

**TEMPOROMANDIBULAR JOINT CHANGES
OCCURRENCE AND DEVELOPMENT**

By

Tore Hansson

Lund 1977

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AKADEMISK AVHANDLING

som för avläggande av odontologie doktorsexamen
vid odontologiska fakulteten, Lunds universitet,
offentligen kommer att försvaras i aulan,
Tandläkarhögskolan, Malmö
fredagen den 29 april 1977 kl. 09.00

av

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leg. tandläkare

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OCCURRENCE AND DEVELOPMENT

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Printed in offset by

LÄROMEDELSCENTRALEN in Lund, 1977



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PREFACE

This thesis is mainly based on the following papers, which will be referred to by their Roman numerals in the text.

- I. Hansson, T. & Nilner, M. 1975. A study of the occurrence of symptoms of diseases of the temporomandibular joint, masticatory musculature and related structures. J Oral Rehabil 2:313-324
- II. Hansson, T. & Öberg, T. 1977. Arthrosis and deviation in form in the temporomandibular joint. A macroscopic study on a human autopsy material. Accepted for publication in Acta Odontol Scand
- III. Hansson, T. & Nordström, B. 1977. Shrinkage of TMJ tissues due to histotechnical treatment. Submitted for publication in Acta Odontol Scand
- IV. Hansson, T., Öberg, T., Carlsson, G.E. & Kopp, S. 1977. Thickness of the soft tissue layers and the articular disk in the temporomandibular joint. Accepted for publication in Acta Odontol Scand 35
- V. Hansson, T. 1977. Thickness of the soft tissue layers and the articular disk in the temporomandibular joint with deviations in form. Submitted for publication in Acta Odontol Scand

DEFINITIONS

Remodelling is to be understood as a rebuilding of adult soft and hard tissue layers.

Deviation in form: deviation from the normally slightly rounded contour of the articular surface.

Arthrosis: a primarily non-inflammatory joint disease, characterized by wear and tear of the articular soft tissues and by remodelling of the underlying hard tissues.
syn.: osteoarthrosis, osteoarthritis, degenerative joint disease.

INTRODUCTION

Diseases of the temporomandibular joints (TMJ) and masticatory musculature can cause a variety of clinical symptoms. The distressing symptoms that have received most space in the literature are chronic pain and pain on movement of the mandible, but also decreased ability to open the mouth wide, locking, jerky movements of the jaw and sounds of the TMJ can be very troublesome (Carlsson & Öberg, 1974 a, b). Several investigations have shown the frequency of the above mentioned symptoms to be fairly high (see Helkimo, 1976).

TMJ sounds are very common and have often been described as the predominant symptoms (Boman, 1947; see Posselt, 1962; Zietz, 1968; Thiel, 1970; Posselt, 1971). Patients frequently refer the pain to the region of the TMJ and ear (Campbell, 1958; Posselt, 1958; Thomson, 1959; Carraro, Caffesse & Albano, 1969; Agerberg, Carlsson, Ericson, Lundberg & Öberg, 1970; Carlsson & Svärdström, 1971; Rosell & Öberg, 1975; Carlsson, Magnusson & Wedel, 1976). It would therefore appear but natural that most authors have assumed the very TMJ to be the site of origin of the symptoms (see De Boever, 1973).

In recent years, however, an increasing number of authors have ascribed the origin of the pain and dysfunction of the masticatory system to the musculature (see Molin, 1973). Also clinical investigations carried out during the last decades have shown that the symptom complex is dominated by tenderness of the masticatory musculature to palpation (Greene,

Lerman, Sutchter & Laskin, 1969; Agerberg et al., 1970; Carlsson & Svärdström, 1971; Rosell & Öberg, 1975).

Epidemiological studies (Hansson & Öberg, 1971; Agerberg & Carlsson, 1973; Helkimo, 1974; Molin, Carlsson, Friling & Hedegård, 1976) as well as a clinical control study (Zarb & Thompson, 1975) have revealed a close association between joint and muscle symptoms, but no dominant cause of the diseases responsible for the symptoms has been found.

The earlier lack of unanimity regarding the site and cause of disease is due partly to the complicated local anatomy (Moffett, 1962; Krogh-Poulsen, 1973; Öberg, 1973; Carlsson & Öberg, 1974 b) which makes a clinical, roentgenological or electromyographical diagnosis technically difficult (Møller, 1974; Petersson, 1976). In addition, nearby structures, such as the ears, nasal sinuses and teeth are common sites of origin of pain.

Other reasons may have been inadequacy of examination methods, differences between such methods as well as the fact that frequency studies have usually been based on examination of clinical materials with an uneven age- and sex-distribution (mainly young women). It is only in the last decade that symptoms referable to the TMJ and masticatory muscles have received attention in the aged (Hansson & Öberg, 1971; Agerberg & Österberg, 1974; Helkimo, 1974) and that clinical and laboratory methods have been devised and standardised (Ahlgren, 1966; Ingervall, 1971; Carlsson & Helkimo, 1972; Eckerdahl, 1973; Agerberg, 1974 a, b; Møller, 1974; Krogh-Poulsen, 1974; Petersson, 1976).

According to De Boever (1973), hypotheses and explanations of symptoms should not be accepted any longer without scientific proof and stressed, as did Helkimo (1976), the need of generally accepted diagnostic and symptomatic criteria so that the findings in different investigations could be compared and thereby facilitate the search for the etiology of the diseases.

Development of specific diagnostic criteria for diseases of the TMJ and masticatory musculature requires better knowledge of the relationship between the patho-anatomical changes and the clinical symptoms. As a link in an endeavour to improve the diagnosis and treatment of diseases related to function of the masticatory system, it was considered legitimate to study a) the various symptoms for any intercorrelations and b) the articulating parts of the TMJ for changes presumably capable of producing symptoms.

REVIEW OF INVESTIGATIONS

I. A STUDY OF THE OCCURRENCE OF SYMPTOMS OF DISEASES OF THE TEMPOROMANDIBULAR JOINT, MASTICATORY MUSCULATURE AND RELATED STRUCTURES

The aim of this investigation was to assess the occurrence of clinical signs of diseases of the temporomandibular joint (TMJ) and masticatory musculature and changes of the teeth related to function.

MATERIAL AND METHODS

The material consisted of 1069 persons working in a ship-building yard in Malmö, Sweden (772 white collar workers and 297 tradesmen). There were only 82 women, all white collar workers. Each participant was examined by one of the two investigators. Whether a person was to be examined by one examiner or the other was decided by chance. The examination days were also randomly chosen by the authors.

The following specially devised limited examination form was used as the examination time for each individual was restricted to 5 minutes.

EXAMINATION FORM

History: reg.no.: name:
 (all questions posed by the examiner)
 Age: sex: occupation:

History

1. Do you find it difficult to open your mouth wide? yes ☐ no ☐
2. Is it painful to open your mouth wide? yes ☐ no ☐
3. Do you hear any clicking sound from the TMJ when you open your mouth wide? yes ☐ no ☐
4. Do you often have a headache? yes ☐ no ☐
5. Do you ever have pain in your ears or in front of your ears? yes ☐ no ☐

Status

1. Maximal opening capacity of the mouthmm
2. TMJ-sounds

clicking right	☐	clicking left	☐
crepitation right	☐	crepitation left	☐
3. Tenderness to palpation

lateral part of TMJ right	☐	left	☐
posterior part of TMJ right	☐	left	☐
4. Tenderness of TMJ musculature to palpation

deep masseter right	☐	left	☐
superficial masseter right	☐	left	☐
anterior temp right	☐	left	☐
posterior temp right	☐	left	☐
med. pteryg right	☐	left	☐
posterior digastric right	☐	left	☐
temp attachment right	☐	left	☐
lat. pteryg right	☐	left	☐
5. Premolar-molar support

lacking right	☐	left	☐
Molar support lacking right	☐	left	☐
6. Prosthesis

maxilla	☐	mandible	☐
---------	--------------------------	----------	--------------------------
7. Asymmetric sliding from RCP^x to ICP^x

to the right	☐	to the left	☐
--------------	--------------------------	-------------	--------------------------
8. Occlusal interferences in the hinge movement of the mandible

right	☐	left	☐
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9. Abrasion:

degree 2	☐	degree 3	☐
occasional teeth	☐		☐
anterior teeth	☐		☐
premolar-molar region	☐		☐
generally in the dentition	☐		☐

^x RCP = retruded contact position, ICP = intercuspal position

The participants were asked to answer only "yes" or "no" to questions about their clinical history.

The different steps of the clinical examination were performed in standardised ways described by Ingervall (1971), Helkimo, Ingervall & Carlsson (1971), Carlsson & Helkimo (1972), Lindqvist (1973) and Agerberg (1974 a).

The χ^2 -test was used in the statistical evaluation of the correlation between pertinent variables and differences between various groups. Owing to the size of the sample, only highly significant ($p < 0.001$) differences were considered.

RESULTS

Clinical history. - A remarkable number of the subjects were aware of clicking of the temporomandibular joint (23%) and many (18%) reported that they often (more than twice a week) had headache. In 6% and 3%, respectively, opening of the mouth wide was reported as difficult or painful. Pain in, or in front of, the ears was reported by 7%.

Clinical examination. - The mean maximal range of opening of the mouth in the entire sample was 53.3 mm.

Temporomandibular joint-sounds were the most common symptom and were noted in 65% of the subjects. Clicking was often bilateral, while crepitation was usually unilateral (Table I).

Table I. Distribution of TMJ-sounds

TMJ-sounds	Unilateral	Bilateral	
Clicking	143	300	443
Creptitation	137	83	220
Creptitation on one side and clicking on the other		31	31
	280	414	694
			65%

Tenderness of the temporomandibular joint to palpation was reported by 10%.

Tenderness to palpation of one or more muscles was noted in 37%. The lateral pterygoid muscle and the temporal muscle showed the highest frequency of tenderness, 29% and 19%, respectively.

Thirty per cent of the participants had two or more of the above-mentioned clinical symptoms, mostly combined temporomandibular joint-sounds and tenderness of masticatory muscles to palpation. Twenty-four per cent had no molar support, unilateral or bilateral, and 22% had a removable prosthesis in one or both jaws.

Asymmetric sliding from RCP to ICP was noted in 29%, and 62% showed occlusal interferences in the posterior path of closure of the mandible. Twelve per cent showed advanced or severe abrasion.

CORRELATIONS

Muscles tender to palpation - difficulties and/or painful wide opening of the mouth.

Frequent headache - tenderness to palpation of the posterior part of TMJ and tenderness to palpation of the posterior digastric and lateral pterygoid muscles.

Pain in, or in front of, the ears - tenderness of TMJ to palpation as well as tenderness of the deep masseter muscle.

Tenderness of the attachment of the temporalis and/or lateral pterygoid muscle - tenderness of TMJ laterally.

Pain on maximal opening of the mouth - frequent headache.

Increased abrasion - number of lost teeth.

II. ARTHROSIS AND DEVIATION IN FORM IN THE TEMPOROMANDIBULAR JOINT. A MACROSCOPIC STUDY ON A HUMAN AUTOPSY MATERIAL

The aim of the study was closely to analyse a previously described autopsy material (Öberg, Carlsson & Fajers, 1971) concerning the occurrence of macroscopically detectable deviations in form, and the presence and character of arthrosis.

MATERIAL AND METHODS

The right TMJ from 115 individuals, aged 1 day - 93 years,

were examined macroscopically in accordance with written descriptions, drawings and photographs taken in color and black and white. Deviations in form and arthrosis of the components were classified according to their extent as local or extensive. Arthrosis of the components was also classified according to depth as shallow or deep. The localization of the deviations in form and/or arthrotic lesions was determined.

RESULTS

Findings were noted only in the adult (> 20 years of age) portion of the material. Forty-eight of 102 joints revealed some form of change. Deviations in form were observed in 45 of the 48 joints and arthrosis in 24. Such deviations were most common in the condyle and arthrotic lesions in the disk and temporal component.

The deviations were predominantly local and confined mainly to the lateral third of the joint.

In 21 joints both deviations in form and arthrotic lesions were noted. In 19 of these, such deviations in form of the condyle were combined with arthrosis of the disk. All but one of these had perforations. Of these 18 arthrotic disks, 13 were associated with arthrotic changes in the temporal component.

Of the 24 arthrotic joints, 4 had extensive lesions affecting all the components in three joints and only the temporal component and the disk in the fourth. Twenty showed local

lesions. Of these joints, only one exhibited changes in all the three joint components. In 10 TMJs the arthrotic lesions were demonstrated in both the disk and the temporal component. Six joints had arthrosis solely in the disk, and three solely in the temporal component.

The lesions were generally found in the lateral portions of the joint. The lesions were also most common in the disk, in the middle dense portion, and in the corresponding articulatory surfaces on the posterior slope of the articular eminence and lateral wall of the fossa. Most of the lesions were deep.

III. SHRINKAGE OF TMJ TISSUES DUE TO HISTOTECHNICAL TREATMENT

The aim of the study was to estimate the shrinkage of the dense part of the disk due to treatment with conventional histological techniques.

MATERIAL AND METHODS

Right human temporomandibular disks obtained at five autopsies of adults were immediately placed in physiological saline, after which they were cut sagittally into 4 equally thick slices. The width of the thinnest as well of the thickest portion of the dense middle part was measured with a

special instrument graduated in 1/10 mm.

The slices were afterwards passed through 10% neutral formalin solution and 70%, 96% and 99.5% alcohol to xylene and measured again.

The preparations were then embedded in paraplast with a melting point of 56-57°C. Three sagittal sections (5-6 μ) were taken from each slice and stained with eosin-haematoxylin, van Gieson's connective tissue staining and toluidine blue, and the thinnest and the thickest parts were measured in a Leitz light microscope with a measuring ocular.

RESULTS

Shrinkage during passage from physiological saline to xylene was significant ($p < 0.05$) but was less than 10% with 95% certainty. No difference in thickness was found between the slices treated up to xylene and the stained sections.

IV. THICKNESS OF THE SOFT TISSUE LAYERS AND THE ARTICULAR DISK IN THE TEMPOROMANDIBULAR JOINT

The aim of the study was to determine the range of variation of the thickness of the soft tissue layers of the temporal component, the condyle and the disk of the healthy TMJ.

MATERIAL AND METHODS

Of the original material consisting of 115 right temporo-mandibular joints (see paper II), 48 that were macroscopically classified as healthy were used for the present investigation.

The articulating joint components were cut sagittally, each into four parts. The total thickness of the soft tissue layers was measured in decalcified stained sections, from the medio-central and lateral parts of the condyle and the temporal components and of the stained sections from the medial, medio-central, latero-central and lateral regions of the disk. In the medio-central sections from the condyle and temporal component the thickness of the fibrous connective tissue layer i.e. the surface layer was also registered.

The occurrence of the undifferentiated mesenchyme layer, the proliferation layer, was registered in the different measuring areas in the medio-central parts of the temporal component and condyle.

Student's t-test was used in the statistical analysis.

RESULTS

The total thickness of the soft tissue layers varied widely. In the condyle the thickest area was superiorly ($\approx$ 0.5 mm) and the thinnest posteriorly ($\approx$ 0.2 mm). In the temporal component the thickest area was on the postero-inferior slope of the articular tubercle ($\approx$ 0.5 mm) and the thinnest in the

roof of the fossa (≈ 0.1 mm). The disk was thickest posteriorly (≈ 3 mm) and thinnest in the middle part (≈ 1 mm).

The soft tissue layers on the condyle as well as the disk were thinner laterally, while the corresponding tissue in the temporal component was thicker laterally.

In the adult portion of the material there was in the areas with the thickest tissue layers less undifferentiated mesenchyme than in the thinner parts.

V. THICKNESS OF THE SOFT TISSUE LAYERS AND ARTICULAR DISK IN TEMPOROMANDIBULAR JOINTS WITH DEVIATIONS IN FORM

The aim of the study was to determine the thickness of the soft tissue layers and the occurrence of the undifferentiated mesenchyme layer in TMJs with deviations in form in an endeavour to elucidate micromorphological changes responsible for the development of gross deviations in form and surface lesions.

MATERIAL AND METHODS

Of 115 right temporomandibular joints from Swedish subjects, aged 1 day to 93 years, 24 of the 102 adult joints exhibited only deviations in form (paper II). Twenty-two of these affected joints were examined histologically regarding the thickness of the soft tissue in the lateral and medio-central

parts of the condyle and temporal component as well as in the lateral, latero-central, medio-central and medial parts of the disk.

The total thickness of the soft tissue layers was measured microscopically in sagittal sections in the anterior, middle and posterior parts of the joint component according to a method described in paper IV.

The surface layer (articulating layer) was, as in the earlier investigation, measured separately in the medio-central part of the condyle and of the temporal component. In these parts of the joint components the amount of undifferentiated mesenchyme was also registered according to a four-graded scale.

Student's t-test was used in the statistical analysis. Within each joint Spearman's rank correlation coefficient was calculated as a measure of the covariation between the amount of mesenchyme and the thickness of the soft tissue layers.

RESULTS

The soft tissue layers were thickest in the lateral part of the condyle superiorly, laterally on the anterior and postero-inferior slopes of the articular tubercle of the temporal component, and posteriorly in the medio-central portion of the disk.

The amount of undifferentiated mesenchyme varied widely, but was completely missing in the superior part of the con-

dyle in 59% and in the postero-inferior slope of the articular tubercle in 78% of the examined joints. The amount of undifferentiated mesenchyme and the thickness of the soft tissue layers varied inversely.

DISCUSSION

The results of the investigation of the frequency of clinical symptoms and signs of diseases of the TMJ, masticatory musculature and changes of the teeth related to function (paper I, Hansson & Nilner, 1975) agree well with those of recent Scandinavian epidemiological studies (Hansson & Öberg, 1971; Agerberg & Carlsson, 1973; Helkimo, 1974; Agerberg & Österberg, 1974), in spite of the fact that the former was carried out on a material consisting mainly of men. The last-mentioned studies revealed no clear differences with sex, but they did give reason to assume that symptoms of diseases of the masticatory system are more common in the aged than previously supposed. In the clinical examination the methods used were the same as those which are used in all departments of stomatognathic physiology in Sweden and may thus be regarded as standardised. The frequency of symptoms and signs in paper I therefore presumably hold not only for white collar workers and tradesmen employed at a large industry, but also for the population of Sweden in general.

The highly significant correlations in paper I between the symptoms reported by the patients and the findings made at the clinical examination indicate that answers to a few questions concerning the clinical history in the routine dental examination is sufficient for the dentist to decide whether a more detailed stomatognathic physiological examination of the masticatory system is indicated.

In view of the wide range of variation of the extent to

which patients can open the mouth - mean 53 mm - together with the fact that many who could open the mouth to an extent close to the mean reported pain referable to the TMJ and the masticatory musculature (paper I), it would not appear warranted to regard values below a certain level, formerly often 40 mm, as decreased or impaired. Also Agerberg & Österberg (1974) questioned the validity of the above limit. Clinically, the maximum extent to which a patient can open the mouth should be related to the mean for the age group to which the patient belongs (Agerberg, 1974 c). However, regular reexamination of a patient's ability to open the mouth wide will often reveal any changes in the condition of the masticatory system, since the ability is usually clearly decreased in the presence of disease (Agerberg et al., 1970; Carlsson & Svärdström, 1971; Rosell & Öberg, 1975; Carlsson et al., 1976).

The results in paper I confirm the results from the epidemiological studies (see Introduction) that most often there exist symptoms referable to both the TMJ and the musculature.

Temporomandibular joint sounds in the form of clicking or crepitation were the most common symptoms (paper I). "Not only condyle - disk displacement (subluxation) and incoordination of the muscles, but also remarkable macroscopic remodelings" (deviations in form) "appear to play an important role in the causation of irregular movements of the jaw and joint sounds" (Carlsson & Öberg, 1974 b). This was corroborated by the finding of such deviations in form in 45% of the postmor-

tem series (paper II, Hansson & Öberg, 1977) and in 44% (paper I) of industrial workers with clicking of the TMJ. Also the results of a clinical-radiographical study (Nanthaviroj, Omnell, Randow & Öberg, 1976) lend support to the view that there exists a relationship between "locking"/clicking of the TMJ and deviations in form. Crepitation is a sign of arthrotic lesions in the components of the joint. It was also interesting to note the good agreement between the frequency of crepitation (paper I) and that of macroscopic arthrosis (paper II). They were demonstrated in about 24%.

The findings in a macroscopic investigation by Bean, Omnell & Öberg (1977) suggest that deviations in form of the TMJ are due not only to remodelling of hard tissue, but also to a large extent to variation of the thickness of soft tissue. It is clear from paper V (Hansson, 1977) that in TMJ with deviations in form the soft tissue layers of the condyle as well as of the temporal component are thicker than in healthy TMJs. The increase in thickness of the soft tissue layers is due to cellular proliferation and new formation of cartilage from the undifferentiated mesenchyme, proliferation layer, (Blackwood, 1966 a, b; Öberg, Fajers, Lohmander & Friberg, 1967). The changes of the TMJ were situated mainly in the lateral parts of the joint (paper II), a finding in agreement with the results obtained in another postmortem study (Bean et al., 1977). It was also in these parts that the soft tissue layer was thickest in the temporal component and the condyle when the joint revealed deviations in form (paper V).

The anatomical characteristics of the deviations in form and the relation in position to one another clearly showed that biomechanical factors were acting as stimuli of cellular proliferation and new formation of cartilage causing the changes. The significance of these biomechanical stimuli has also been stressed by Moffett, Johnson, McCabe and Askew (1964) and Blackwood (1966 b). Folke & Stallard (1966) found that "the embryonic zone of the condylar cartilage" in rats could be stimulated to increase cellular division in order to follow the changes in position of the mandible. That increased biomechanical loading in a joint can stimulate cellular proliferation and new formation of cartilage has been shown also by Telhag (1973, 1977) in experimental studies of the knee and hip joints in animals. The changes afterwards led to arthrosis.

In the joints with deviations in form (paper V) the areas exposed to the largest loads had much less undifferentiated mesenchyme than the healthy joints (paper IV, Hansson, Öberg, Carlsson & Kopp, 1977) and the amount of undifferentiated mesenchyme varied inversely with the thickness of the soft tissue layers (paper V). This suggests that the ability to proliferate and form new cartilage can be impaired.

In joints with deviations in form the disk was thinner laterally (paper V). This was obviously because the disk cannot proliferate because of its lack of undifferentiated mesenchyme in contrast with the condyle and the temporal component. The disk must therefore passively adapt itself to the deviations in form of the other two articulating components. The

thickness of the surface layer (articulating layer), which structurally agrees largely with the dense part of the disk, did not differ with the presence or absence of deviations in form. Evidently then also the surface layer adapts itself passively to the changes in the underlying tissue layers, a conclusion made previously by Öberg (1964), Blackwood (1966 b) and Öberg et al. (1967).

Remodelling of the soft tissue is accompanied by remodelling of the underlying hard tissue, which is to be studied separately.

Arthrotic lesions practically always appeared with deviations in form and are most often situated laterally in the joint (paper II) as has been found also in postmortem studies (Bean et al., 1977) and are obviously secondary to the deviations in form. Arthrotic lesions occur most often in the disk and in the temporal component. This fact may be ascribed to the lack of undifferentiated mesenchyme in the disk and primarily smaller amount of it in the temporal component than in the condyle (Öberg, 1964). This explains the higher frequency of deviations in form and the rareness of arthrotic changes in the condyle (paper II). The undifferentiated mesenchyme appears to offer protection thanks to its ability to form cartilage, which by virtue of its high content of proteoglycans increases the tolerance of the joint to pressure (Heinegård, 1977).

Arthrotic lesions occur mainly in the temporal component in the area exposed to most pressure i.e. the posterior slope of the tuberculum articulare and in the dense middle part

of the disk. Arthrosis often occurs also in the lateral wall of the fossa and juxtaposed area of the disk corresponding to the deviation in form of the condyle. In the fossa, which is normally exposed to only little pressure and where the soft tissue layer with the undifferentiated mesenchyme is normally thin, the repair capacity is also less.

The changes and increased functional loading which stimulates the continuous remodelling processes in both the soft and the hard tissue layers to deviations in form and later development into arthrosis may be due to extensive loss of teeth (Öberg et al., 1971; Kopp, 1977) and abrasion (Bergman & Hansson, 1977). Other possible factors contributing to the changes might be cuspal interferences and bruxism. The development of deviations in form may result in disturbed movement of the jaw and clicking (Nanthaviroj et al., 1976) with a risk of simultaneous incoordination of the masticatory musculature (Palmquist & Öberg, 1971; Nanthaviroj et al., 1977) and associated further increase of the unfavourable loading. Against this background the frequency of the joint sounds combined with tenderness of the masticatory muscles to palpation (paper I) is interesting.

The distribution of tenderness to palpation with a predilection for the lateral pterygoid muscle and the temporal muscle was the same as that found by Hansson & Öberg (1971), Agerberg & Österberg (1974) and Helkimo (1974). However, the total frequency of tenderness of the musculature to palpation varies somewhat, but is clearly lower than that found in clinical materials.

The total thickness of the soft tissue layers of the condyle, disk and temporal component (paper IV and V) must be regarded as useful as a reference in the evaluation of tissue changes, and in the roentgenological examination of the TMJ. The thickness is probably reduced by 10% owing to shrinkage (paper III, Hansson & Nordström, 1977). A search of the literature failed to reveal any measurements of the soft tissue layers in healthy TMJs. Moffett et al. (1964), however, reported a rough estimation of "the thicknesses of the articular tissue" in joints where changes appeared to have occurred. The measurements were made only in areas exhibiting deviations in form which can explain the present difference between these values and those reported in paper V.

CONCLUSION

The frequency of signs suggesting diseases related to function of the masticatory system is high. Such symptoms can be diagnosed or confirmed by a simple routine examination.

There is a close correlation between joint symptoms and muscle symptoms. Symptoms in the form of clicking and crepitation indicate changes such as deviation in form and arthrosis of the articulating components of the TMJ.

The character, localization and extent of the changes in the articulating temporomandibular joint components reflect the changes in functional loading of the joint.

An increase in the biomechanical loading of a joint stimulates cellular proliferation and cartilage formation from the undifferentiated mesenchyme resulting in thickening of the soft tissue layers which contributes to the development of deviations in form of the temporal component and the condyle and secondary changes of the disk. Such deviations in form can cause disturbances of movements, jerky movements of the jaw, clicking and with proceeding unfavourable loading gradually lead to arthrosis with crepitation as a clinical symptom.

ACKNOWLEDGEMENTS

Sincere thanks go to:

Professor Torsten Öberg, my chief, who aroused my interest in his field of research, for valuable and constructive suggestions and criticism; Professor Torsten Öberg together with Professor Gunnar E. Carlsson and the late Professor Carl-Martin Fajers, for placing their original material at my disposal; Miss Birgitta Nordström, for most skilful laboratory assistance; Mrs Louise Håkansson for excellent typing and secretarial help; Civil engineer Tore Persson for statistical analysis; and Miss Gunborg Bülow and Mrs Tosca Engel for bibliographical assistance.

This work was supported by grants from the Faculty of Odontology, University of Lund.

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A study of the occurrence of symptoms of diseases of the temporomandibular joint masticatory musculature and related structures

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Summary

An examination of the temporomandibular joints, masticatory musculature and related structures was made on 1069 persons working in a ship-building yard in the south of Sweden. One-fifth of the persons reported that they had frequent headache and one-fourth of the persons reported TMJ-sounds.

Clinical examination of the temporomandibular joints and masticatory musculature showed that clicking of the TMJ was the most common symptom (65%) followed by tenderness of the masticatory musculature to palpation (37%) and tenderness of the temporomandibular joint (10%). Thirty per cent of the persons examined reported two or more of these symptoms. Severe abrasion was noted in 12%.

The results of the investigation suggested that the frequency of diseases related to function of the masticatory system is high. It was estimated that some 25–30% of the persons examined were in need of treatment.

Introduction

Estimation of the frequency, and need for treatment of, changes and diseases related to function in the masticatory system, requires extensive epidemiological investigation.

Earlier investigations (Boman, 1947; Franks, 1964; Zietz, 1968; Carraro, Caffesse & Albano, 1969; Thiel, 1970; Carlsson & Svärdröm, 1971) have appraised the frequency of different symptoms referable to the temporomandibular joints and the masticatory muscles. The sex distribution, as well as the age distribution, has been described as left-skewed. The investigations have one thing in common, namely, that they have been performed on patients, especially those attending dental schools and hospital departments. Therefore they do not reflect the situation in the general population.

Epidemiological studies have been started recently in Scandinavia to obtain an estimation of the true frequency of diseases related to function of the masticatory system, of the frequency of the various symptoms, and of the true age and sex distribution of the changes. It is widely assumed that diseases of the temporomandibular joint and masticatory musculature are not very common and occur most often in women, particularly between the ages of 20 and 50 years. In an investigation of 67-year-old persons in Dalby by Hansson & Öberg (1971), it was found, however, that

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such symptoms were very common (73 %) and it appears that even the aged have such diseases more often than has been supposed. Results of investigations of Skolt and Enare lapps in the north of Finland by Helkimo *et al.* (1972) also suggest a high frequency of diseases causing dysfunction of the TMJ and the masticatory musculature.

Agerberg & Carlsson (1972) corroborated these figures in an investigation by questionnaire of the population of Umeå. They speculated that the dominance of women in their series was due to the tendency of women to visit the dentist or physician more often than men.

In the spring of 1971 those persons who had received dental examinations between November 1964 and April 1966 by H. Björn and co-workers were re-examined at Kockums Mekaniska Verkstads AB, Malmö. In connection with that investigation the present authors had the opportunity to make a clinical oral physiological examination. After the periodontal examination an additional interview and clinical survey of each person was carried out.

Materials and methods

In November 1964 Kockums Mekaniska Verkstads AB employed about 5100 white-collar workers and tradesmen. The former group consisted of 1700 persons, 1431 of whom were men. The number of tradesmen was 3400. During the dental examinations by Björn and co-workers between November 1964 and April 1966, notes were made on the condition of the teeth in 1219 white collar workers. Of the tradesmen, subjects were selected from each fifth age group between 20 and 65 years, altogether 746 persons. The status of the teeth was examined in 652 of them (Björn, 1971). Of the employees participating in the original investigation, 1116 were re-examined for general dental condition in the spring of 1971. The present authors examined 1069 of them (772 white collar workers and 297 tradesmen) to determine the occurrence of temporomandibular joint, masticatory muscular, and related disorders. The distribution of the participants according to age, sex and occupation is given in Table 1. The table shows that most of

Table 1. Distribution of material according to sex, age and occupation

Age	White-collar workers		Tradesmen	Total
	Men	Women	Men	Men + women
10-19	1	2	0	3
20-29	39	36	15	90
30-39	105	9	60	174
40-49	226	17	77	320
50-59	253	16	86	355
60-69	65	2	59	126
70-79	1	0	0	1
	690	82		
	772		297	1069

the participants were from 40 to 59 years old. There were only few women, all white collar workers (82). The 1069 participants were examined by the authors on the premises of the shipbuilding yard. Maria Nilner examined 560 persons and Tore Hansson 509. Whether a person was to be examined by one examiner or the other was decided by

chance. Two to three days a week one investigator (T.H.) examined those persons who had an appointment with the periodontist. The other investigator (M.N.) examined the persons on the remaining days of the week. The investigation was continued in this manner for approximately 4 months during the spring of 1971. The examination days were randomly chosen by the authors.

The following specially devised form was used. Its design is based on experience from earlier investigations (Hansson & Öberg, 1971).

EXAMINATION FORM

History: reg. no.: name:
(all questions posed by the examiner)
Age: sex: occupation:

History

1. Do you find it difficult to open your mouth wide? yes ☐ no ☐
2. Is it painful to open your mouth wide? yes ☐ no ☐
3. Do you hear any clicking sound from the TMJ when you open your mouth wide? yes ☐ no ☐
4. Do you often have a headache? yes ☐ no ☐
5. Do you ever have pain in your ears or in front of your ears? yes ☐ no ☐

Status

1. Maximal opening capacity of the mouth . . . mm
2. TMJ-sounds

clicking right ☐ clicking left ☐
crepitation right ☐ crepitation left ☐

3. Tenderness to palpation

lateral part of TMJ right ☐ left ☐
posterior part of TMJ right ☐ left ☐

4. Tenderness of TMJ musculature to palpation

deep masseter
right ☐ left ☐
superficial masseter
right ☐ left ☐
anterior temp
right ☐ left ☐
posterior temp
right ☐ left ☐
med. pteryg
right ☐ left ☐
posterior digastric
right ☐ left ☐
temp attachment
right ☐ left ☐
lat. pteryg
right ☐ left ☐

5. Premolar-molar support
 lacking right ☐ left ☐
 Molar support lacking right ☐ left ☐
6. Prosthesis maxilla ☐ mandible ☐
7. Asymmetric sliding from
 RCP* to ICP* to the right ☐ to the left ☐
8. Occlusal interferences in the hinge movement of the mandible right ☐ left ☐
9. Abrasion: degree 2 degree 3 degree 4
- | | | | |
|----------------------------|--------------------------|--------------------------|--------------------------|
| occasional teeth | ☐ | ☐ | ☐ |
| anterior teeth | ☐ | ☐ | ☐ |
| premolar-molar region | ☐ | ☐ | ☐ |
| generally in the dentition | ☐ | ☐ | ☐ |

* RCP=retruded contact position, ICP=intercuspal position.

The *clinical history part* of the investigation was based on an interview with the participants. The examiner always had at his disposal an assistant who filled in the forms as soon as the questions had been answered. The assistant also made a note of all findings observed during the clinical examination. With such a system it was possible to keep the examination time for each individual down to 5 min. Concerning the question about frequent headaches, an affirmative answer was noted only if the patient reported headache more than twice a week.

At the *clinical examination* note of maximal opening of the mouth was made in mm. Using a steel rule, the measurement was determined as the distance between the edges of the central incisors (+1 and -1) on 'provoked' maximum opening of the mouth, i.e. the participant opened his mouth as wide as he could. At the same time the examiner requested the participant to try to open the mouth a little more. The distance of the vertical overbite was added to the value observed at maximal opening to obtain the final measurement. The reliability of this measuring technique has been studied by Ingervall (1971). Temporomandibular joint-sounds were analysed with the aid of a stethoscope, which was placed against the skin over the temporomandibular joint, while the participant repeatedly opened and closed his mouth. During palpation of the temporomandibular joint and the mandibular musculature, both sides were palpated simultaneously. Any difference found between the right side and the left was noted. The participant was asked whether palpation caused any discomfort or pain. Notation was made only of pain.

The lack of premolar-molar support or only the lack of molar support, as well as the use of any removable prosthesis and the type of prosthesis, were noted. Notes were made of any gross asymmetric sliding from RCP to ICP as observed with the naked eye. According to Lindqvist (1973), this sliding is probably ≥ 0.5 mm. Occlusal interferences in the hinge movement were noted with the aid of articulation wax (Kerr Casting Wax Sheets, Green-soft no. 28) and/or thin black articulation ribbon (typewriting ribbon Facit), placed between occlusal surfaces of the upper and lower teeth after the examiner had moved the mandible into RCP. The method has been described by Helkimo, Ingervall & Carlsson (1971). As a supplementary measure, the occlusal sound was checked with a stethoscope placed against the skin in the infra-orbital region. A diffuse occlusal sound in RCP also indicates interferences. The degree of abrasion was noted as follows:

Grade 1 = abrasion of enamel only.

Grade 2 = abrasion of tooth substance including wear of the dentine.

Grade 3 = reduction of the length of the crown one-third of the original crown length, or advanced lingual or facial wear.

Grade 4 = pulpal lesion or length of crown reduced by more than one-third.

Notation was made only of abrasion grades 2, 3 and 4.

Analysis of the material was done in co-operation with a statistician (civil engineer Tore Persson, Department of Mathematical Statistics, Lund University). The examination forms were programmed, punched and processed at Lund's Data Central with a Univac 1108. The χ^2 -test was used in the statistical evaluation of the correlation between pertinent variables and differences between various groups. Several levels of significance used were: $P < 0.001$, $0.001 < P < 0.01$, $0.01 < P < 0.05$. Owing to the size of the sample, only highly significant differences were considered.

Results

Clinical history

The answers to the questions are given in Table 2.

Table 2. Results from the clinical history

Question	Answer		
	Yes	No	% yes
Do you find it difficult to open your mouth wide?	61	1008	6
Is it painful to open your mouth wide?	32	1037	3
Do you hear any clicking sound from the TMJ when you open your mouth wide?	246	823	23
Do you often have a headache?	197	872	18
Do you ever have pain in your ears or in front of your ears?	79	990	7

It is clear from this table that a remarkable number of the subjects were aware of clicking of the temporomandibular joint (23 %) and many reported that they often had headache (18 %). In 6 % and 3 %, respectively, opening the mouth was reported as difficult or painful. Pain in, or in front of, the ears was reported by 7 %.

Clinical examination

Ability to open the mouth wide. About three-fourths of the participants could open the mouth 45–60 mm (Tables 3 and 4). Only 22 of the 1069 participants could open the mouth < 40 mm. The mean maximal range of opening of the mouth in the entire sample was 53.3 mm.

Table 3. Distribution of material according to maximal opening of the mouth

Maximal opening (mm)	Number
30-34	1
35-39	21
40-44	63
45-49	219
50-54	311
55-59	261
60-64	140
65-69	37
70-74	16
	1069

Table 4. Sex distribution of maximal opening of the mouth

Maximal opening (mm)	Number	
	Men	Women
30-34	1	0
35-39	19	2
40-44	60	3
45-49	194	25
50-54	284	27
55-59	244	17
60-64	134	6
65-69	36	1
70-74	15	1
	987	82

Temporomandibular joint-sounds were the most common symptom and were noted in 65% of the subjects. Clicking was often bilateral while crepitation was usually unilateral (Table 5). About 10% reported *tenderness of the temporomandibular joint*

Table 5. Distribution of TMJ-sounds

TMJ-sounds	Unilateral	Bilateral	
Clicking	143	300	443
Creptitation	137	83	220
Creptitation on one side and clicking on the other		31	31
	280	414	694
			65%

to palpation. The distribution of this tenderness laterally and posteriorly is given in Table 6. Eighteen participants (2%) reported tenderness of one or both joints to palpation both laterally and posteriorly. *Tenderness to palpation of one or more muscles* was noted in 37% (398 persons). The lateral pterygoid muscle and the temporal muscle showed the highest frequency of tenderness (Table 7).

Combined temporomandibular joint-sounds and tenderness of masticatory muscles to palpation were predominant in cases with two or more of the above symptoms. Thirty per cent of the participants had two or more symptoms (Table 8).

Table 6. Distribution of tenderness of the TMJ to palpation

Tenderness of the TMJ to palpation	Unilateral	Bilateral	
Lateral	50	25	75
Posterior	33	14	47
	83	39	122

Table 7. Distribution of tenderness to palpation of the masticatory musculature

Tenderness to palpation of musculus	Unilateral	Bilateral	%
Masseter (deep)	18	7	2
Masseter (superf.)	16	6	2
Temporalis ant.	6	2	1
Temporalis post.	2	1	—
Temporalis attachment	106	99	19
Pterygoideus lat.	151	159	29
Pterygoideus med.	50	17	6
Digastricus post.	26	13	4

In 6% (66 persons), *premolar-molar support was missing* on one or both sides, while one-fourth (24%), 261 persons, had *no molar support*, unilateral or bilateral. Twenty-two per cent (239 persons) had removable prosthesis in one or both jaws.

Asymmetric sliding from RCP to ICP was noted in 29%. Almost two-thirds or 62% (655 persons) also had *occlusal interferences in the posterior path of closure of the mandible*. *Abrasion grades 2, 3 or 4* as maximal values were noted in 66% (701 persons). One hundred and twenty-eight (12%) had grade 3 or 4 (Tables 9 and 10).

Correlations

A significant correlation was found between the presence of muscles tender to palpation (posterior temporal, deep portion of masseter, anterior temporal, temporalis attachment and lateral pterygoid) and difficult and/or painful wide opening of the mouth.

A significant correlation was found between frequent headache, on one hand, and tenderness to palpation of the posterior part of the temporomandibular joint and tenderness to palpation of the posterior part of digastric and lateral pterygoid.

Almost half of those with tender TMJ had frequent headache (21 of 47) and tenderness to palpation of the lateral pterygoid (82 of 197).

Pain in or in front of the ears was significantly correlated with tenderness of the temporomandibular joint to palpation as well as tenderness of the deep masseter muscle.

A significant correlation was found between tenderness of the attachment of the temporalis and/or the lateral pterygoid and of the TMJ laterally. A significant covariation was also found between pain on maximal opening of the mouth and frequent headache.

Premolar losses were noted significantly more often in age groups from 50 years upwards. Molar losses occurred 10 years earlier. The frequency of loss of molar support was equal among the tradesmen as among the white-collar workers. Interferences were significantly more common among the latter and significantly more common among the women.

Of the 297 tradesmen, 106 had an upper or lower prosthesis, compared with 133 of the 772 white-collar workers. Signs of general abrasion of the tooth substance (grade 2) was found in a large proportion of participants of only 20 years of age. Abrasion grade 3 was found mainly in persons above 50 years (Table 11), but occasionally in the 20

Table 8. Distribution of patients with one, two or more symptoms referable to the TMJ and masticatory musculature

Symptom	Number of individuals			
TMJ-sounds	C	394		
Decreased range of opening of the mouth <40 mm	DO	7		
Temporomandibular joints tender to palpation	JP	10		
Masticatory musculature tender to palpation	MP	115	526	49%
C+DO		9		
C+JP		27		
C+MP		212		
DO+JP		1		
DO+MP		1		
JP+MP		18	268	25%
C+DO+JP		0		
C+DO+MP		4		
C+JP+MP		48		
DO+JP+MP		0	52	5%
C+DO+JP+MP		0	0	
			846	79%

Table 9. Distribution of maximum abrasion

Degree of abrasion	Number examined
<Grade 2	368
Grade 2	573
Grade 3	117
Grade 4	11
	1069

year group. The abrasion increased significantly with the number of teeth lost. Abrasion was significantly more common among the tradesmen than among the white collar workers.

Good agreement was found between the two examiners with regard to the recording of the history. The notations made during the clinical examination differed somewhat between the examiners. Examiner no. 1 (M.N.) recorded clicking of the temporomandibular joint significantly more often than examiner no. 2 (T.H.) while the reverse was true when recording crepitation. Moreover, examiner no. 2 recorded tenderness of the deep masseter, medial and lateral pterygoid, and the temporalis attachment significantly more often than examiner no. 1. Both examiners recorded tenderness of the superficial masseter, anterior and posterior temporalis and the posterior digastric with equal frequency.

Table 10. Distribution of site of abrasion

Severity	Occasional teeth	Frontal region	Premolar-molar region	Generalised in dentition
< Grade 2	835	722	925	888
Grade 2	152	305	136	173
Grade 3	78	42	8	6
Grade 4	4	0	0	2
	1069	1069	1069	1069

Table 11. Age distribution of abrasion

Age	Abrasion			
	< Grade 2	Grade 2	Grade 3	Grade 4
10-19	3	0	0	0
20-29	51	36	3	0
30-39	59	108	7	0
40-49	49	247	24	0
50-59	144	143	62	6
60-69	62	39	20	5
70-79	0	0	1	0

Discussion

The investigation permitted a rough estimation of (1) the frequency of clinical symptoms of the masticatory system associated with diseases of the temporomandibular joint and masticatory musculature, and (2) the degree of dental abrasion in a sample population. Since the clinical sample was large, the findings are probably indicative of what might be expected in a similar group of heavy industry workers. It should, however, be pointed out that in Malmö the number of dentists per thousand inhabitants is fairly high, and that the amount and quality of treatment available to the population is relatively good (Öwall, 1973). In an investigation of a statistical selection of the Swedish population as many as 24% of all persons above 16 years had no natural teeth at all and 31% above 16 years wore a complete upper or lower denture (Smedby, 1965). In our material, on the other hand, only 22% had some form of removable prosthesis.

Despite the few and obviously simple questions used in the interviews, many persons were unable to understand the meaning of the questions without further explanation. This means that, in an investigation of this nature, personal interview with the patients is very important if an accurate opinion is to be obtained on the frequency of symptoms of diseases of the masticatory system.

As many as 92% of the participants could open the mouth more than 45 mm. The mean value was 53.3 mm, being 51.8 mm for the women and 53.4 mm for the men. The values ranged between 30 and 74 mm. In earlier investigations, but of smaller samples, similar values have been found. Lignell & Ransjö (1967) measured maximal opening of the mouth in 436 persons below 26 years of age. The value found for the women was 51 mm and for the men 55 mm. In an investigation of 102 men and 103 women, aged 20 years, Agerberg (1967) found that the men could open the mouth 5.3 mm more than the women (58.6 compared with 53.3 mm). However, in

183 men and women aged 70 years Agerberg (1974) found a lower mean value for maximal opening of the mouth, viz. 50.3 mm. In the present material there was also a clear tendency for maximal opening of the mouth to decrease with advancing age.

In patients with diseases related to function of the masticatory system, clearly lower mean values have been reported. At a central dental polyclinic the range of variation of opening of the mouth was 15 and 62 mm with a mean of 44.3 mm in the 101 persons studied (Öberg & Rosell, 1974). Similar values have been found in material from the departments of stomatognathic physiology (Agerberg *et al.*, 1970; Carlsson & Svärdröm, 1971).

It is obviously wrong to regard maximum opening of the mouth as decreased on the sole basis that a person can only open the mouth less than 40 mm. In a patient who normally can open the mouth 65 mm, opening of the mouth is obviously impaired if he can open it only 55 mm. In the present investigation there were thirty-two persons who found wide opening of the mouth painful though they could open it from 40 to 69 mm. Many of these patients also complained of tenderness of the masticatory muscles to palpation and their ability to open the mouth wide was presumably impaired. This also underlines the importance of careful palpation of the temporomandibular joint in patients who complain of pain when opening the mouth wide during dental treatment. It is not always a sign of fatigue due to keeping the mouth open during treatment. It might very well be a symptom of disease of the temporomandibular joint and masticatory musculature.

As in earlier investigations, temporomandibular joint-sounds were the most common symptoms. Yet most of those with such symptoms were unaware of them. However, significantly more were aware of them when they were bilateral. A number of participants reported temporomandibular joint-sounds which could not be verified. This may, perhaps, be because clicking occurs only periodically in some persons. Clicking may be due to various factors such as remodelling, displacement of the condyle and the disc, and muscular inco-ordination (Carlsson & Öberg, 1974). Both occasional and regular clicking may be troublesome to the patient. With the continuously recurring microtrauma of the temporomandibular joint, and disturbance of function of the masticatory musculature, clicking is probably of greater clinical significance than hitherto supposed (Palmquist & Öberg, 1971). Crepitation was noted in 24% and occurs when rough joint surfaces move against each other. It is often a sign of a more serious disease than that associated with clicking and is regarded as one of the clinical symptoms of arthrosis. In a Swedish autopsy series of subjects aged 20–93 gross arthrosis was seen with roughly the same frequency, 22% (Öberg, Carlsson & Fajers, 1971).

Palpation tenderness of the masticatory muscles was a common symptom (37%), with marked dominance of the lateral pterygoid and temporalis muscles. The temporomandibular joints were not so frequently tender (10%) as the masticatory musculature. Similar figures have been given by Hansson & Öberg (1971) in an investigation of 67-year old persons in Dalby, and by Helkimo *et al.* (1972) in an investigation of Skolt and Enare lapps.

In patients seen in dental schools and hospitals the frequency figures are much higher. Thus, tenderness of the musculature to palpation has been reported with a frequency of 60–84% and such tenderness of the temporomandibular joint between 36 and 75% (Agerberg *et al.*, 1970; Carlsson & Svärdröm, 1971; Öberg & Rosell, 1974).

In recent years during investigations of diseases related to function of the masticatory system, interest has been concentrated on the temporomandibular joint and masticatory muscles. The results of the investigations regarding dental abrasion, which is probably most often related to function, clearly point to the need for methods to discover the causes of these injuries to the masticatory system in order to facilitate effective prophylaxis and therapy. As many as 128 of the persons examined had abrasion of degree 3 or 4. It was also remarkable that advanced abrasion was seen in persons between 20 and 30 years of age. In this age group 43 % had abrasion of grade 2 or more. The correlation between the grade of abrasion and loss of teeth was highly significant. The lack of premolar-molar support, and lack of molar support alone, was equally frequent among the tradesmen as among the white collar workers. The higher frequency of abrasion among the tradesmen was therefore remarkable. There may be several factors that contribute to this difference in the occurrence of abrasion. Dusty atmosphere, bruxism and reduced secretion of saliva are examples of possible factors.

There was a difference between the examiners regarding the results of palpation of the masticatory musculature. It should, however, be observed that examiner no. 1 recorded lack of molar support and prosthesis significantly more often, and found more interferences and more abraded teeth than examiner no. 2. This suggests a certain difference in the distribution of the material between the two examiners in this investigation.

The frequency figures for symptoms of the temporomandibular joint and masticatory musculature were 79 % and corresponded to the frequencies found by Hansson & Öberg (1971) in an investigation of 67-year-old persons in a south Swedish community, and by Helkimo *et al.* (1972) in an investigation of a population in the north of Finland. These investigations thus suggest that diseases correlated to function of the masticatory system are more common than formerly assumed. Not all of the persons with changes were in need of treatment. As judged from the histories in the present study and clinical symptoms of the muscles and joints as well as the dentition, it is suggested that some 25–30 % were in need of treatment. There is obviously a latent need, the existence of which recently has been supported by a considerable increase in the number of persons seeking dental treatment of the symptoms. The number of specialists in stomatognathic physiology will probably increase, but the general dental practitioner must also treat patients with temporomandibular joint symptoms to a greater extent than is now the case in order to satisfy the increased need for treatment. From that point of view it is important that dental practitioners become better acquainted with the diagnosis and treatment of these problems. In many cases minor correction of the dentition is sufficient to give the patient considerable relief. In some cases complete relief and healing of a pathological process is achieved. A few short questions and a simple clinical examination are often enough to give the dentist a good idea of the cause of temporomandibular joint dysfunction in a given case. The dentist can give the patient relief by such treatment as grinding, insertion of an occlusal splint and, if necessary, prosthetic treatment.

Epidemiological investigations of the occurrence of temporomandibular joint symptoms in northern communities have shown good agreement. They have one thing in common, namely that they were concerned with symptoms and not with the disease *per se*. In the future more attention should be given to the diseases responsible for the symptoms.

Acknowledgments

Thanks are due to Professor Torsten Öberg for his advice and guidance during the study and for reviewing the manuscript; to Professor Hilding Björn for letting us participate in his study; to civil engineer Tore Persson for his statistical help; and, to laboratory assistant Birgitta Nordström for valuable assistance with the clinical examination.

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ARTHROSIS AND DEVIATION IN FORM IN THE TEMPOROMANDIBULAR
JOINT.

A MACROSCOPIC STUDY ON A HUMAN AUTOPSY MATERIAL

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The right TMJ from 115 individuals, aged 1 day - 93 years, were examined macroscopically regarding the occurrence of deviation in form and arthrosis in the three articulating joint components. The changes were classified according to extent. In addition, the depth of the arthrotic lesions was determined.

Nearly half (48 of 102) of the adult TMJs revealed some form of change. No changes in the joint surfaces were noted from individuals under 20 years of age.

Deviations in form occurred in 45 of the 48 affected joints and arthrosis in 24. The deviations in form were most common in the condyle while arthrotic lesions were noted mainly in the disk and temporal component of the joint.

The changes were usually local in nature and located in the lateral one-third of the joint.

Key words: Deviation in form of TMJ; Morphology: human re-modelling

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Accepted for publication in Acta Odont. Scand. 1977

Studies of autopsy material have shown that deviations in form (Öberg, Carlsson & Fajers, 1971) as well as arthrosis (Blackwood 1963 and Öberg et al. 1971) commonly occur in the temporomandibular joint (TMJ). Biomechanical factors evidently play a large role in the occurrence of

arthrosis as shown by Telhag (1973) through experimental studies on the knee joint of the rabbit. Öberg et al. (1971) have also shown that extensive tooth loss is a predisposing factor for the occurrence of changes in shape and arthrosis in the TMJ. The aim of the present study has been to more closely analyse the previously described autopsy material (Öberg et al. 1971) concerning the occurrence of macroscopically detectable deviations in form and the presence and character of arthrosis. These findings have then been discussed in relation to the function of the TMJ.

MATERIAL AND METHOD

The material consisted of the right TMJ from 115 individuals, aged 1 day - 93 years, of which 102 were adults (20 years or older). The joints had been dissected and the appearance of the joint components described. The temporal component had, in all cases, been photographed from below and also, when necessary, from supplementary directions for documentation of noteworthy changes. All condyles had been photographed from above and in front and in cases where changes in form or surface lesions had been noted photographs were also taken laterally and posteriorly. As a rule the disk had been photographed both from above and from in front. Photographs had also been taken of the inferior and lateral portions when notable changes were detected.

Öberg et al. (1971) divided the present material according to the type of dentition into three main groups:

- I Complete or almost complete set of teeth with bilateral molar support.
- II Considerable loss of teeth, reduced dentition without molar support.
- III Edentulous, with or without complete denture replacement.

The joints were evaluated concerning deviations in form and occurrence of arthrosis after examination of written descriptions, drawings and photographs taken in color and black and white.

For closer scrutiny the temporal component, condyle and disk were subdivided as shown in Fig. 1.

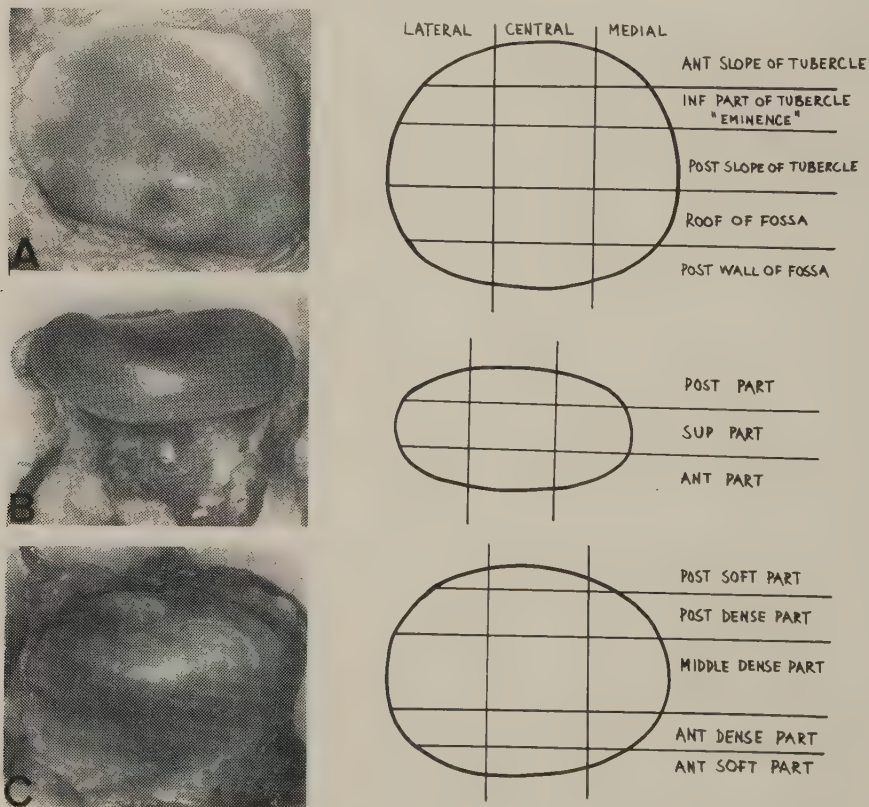


Fig. 1. Division of the articulating joint surfaces. Temporal component A (from below), condyle B (from above) and disk C (from above).

Deviations in form and arthrosis of the components

were classified according to extent into:

1. Local ($< 1/3$ of the joint surface involved).
2. Extensive ($\geq 1/3$ of the joint surface involved).

Arthrosis of the components was also classified according to depth into:

1. Shallow (lesion of the joint surface which was velvet-like to slightly scalloped in nature).
2. Deep (lesion which resulted in a loss of substance in the soft tissue to, or in the region of, the underlying hard structures. A "deep" arthrosis in the disk always denoted a perforation).

The localization of the deviations in form and arthrotic lesions were determined. When possible, the disk was also examined for the presence of dark-colored areas interpreted as changes in blood vessels.

RESULTS

In the ages below 20 years no signs of morphologic changes, arthrosis or discoloration of the disk were noted in the joints examined. In the remaining portion of the material the following findings were noted.

As shown in Table I, nearly half (48 of 102) of the adult

Table I. Classification of the adult joints

		20-39 years	40-93 years
Normal joints	53	14	39
Joints with only deviations in form	24	8	16
Joints with only arthrosis	3	1	2
Joints with both deviations in form and arthrosis	21	0	21
Malformed joint	1	1	0
Total joints	102	24	78

TMJs revealed some form of change. Deviations in form occurred in 45 of the 48 affected joints and arthrosis in 24. Deviations in form were most common in the condyle and arthrotic lesions in the disk and temporal component of the joint (Table II).

Table II. Detectable changes with respect to joint component

Change Joint component	Deviation in form	Arthrosis
Temporal component	27	18
Condyle	40	4
Disk	23	21

In the group revealing only deviations in form (Fig. 2.) the

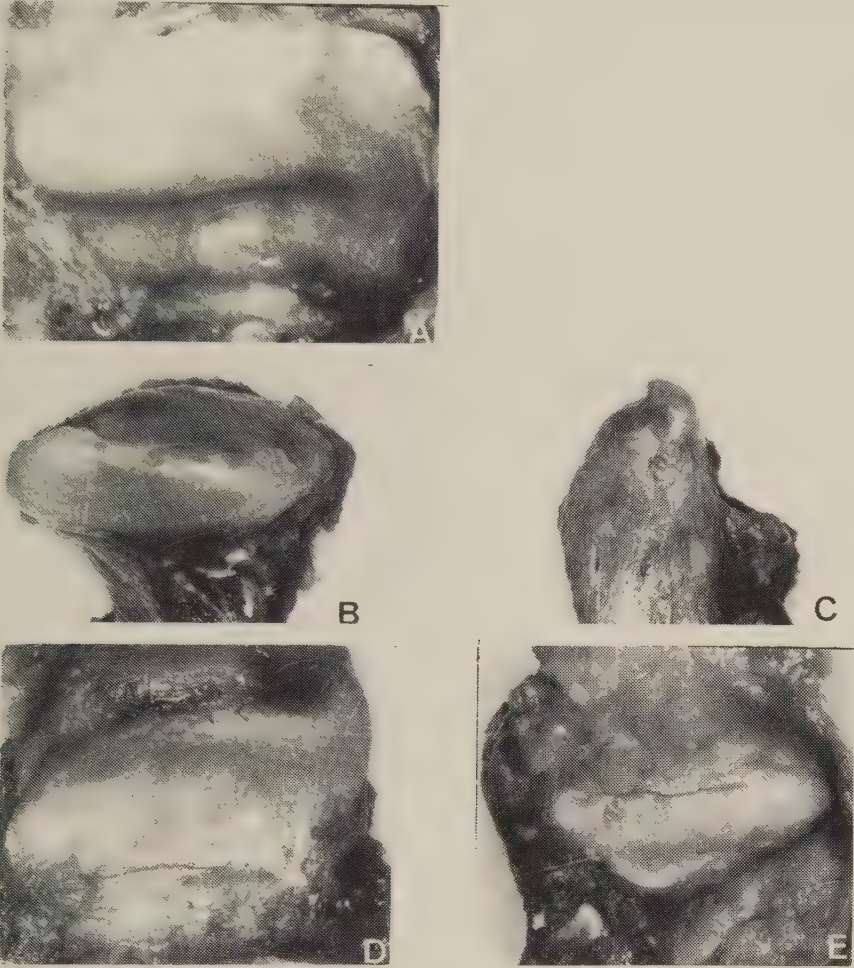


Fig. 2. A: Temporal component (from below) with elevation of the lateral and central parts of the articular tubercle. B and C: Condyle (from above and laterally) with supero-anterior bulging corresponding to the elevation on the articular tubercle and the concavity located posteriorly on the condyle which has resulted in a medio-lateral edge superiorly. D and E: Disk (from above and below respectively), the surfaces of which have been adapted to the shape of the condyle and temporal component. Note the groove in the inferior surface of the disk, resulting from the superior edge of the condyle.

combination of changes in the condyle and disk was noted most often (15 joints). Deviations in form only of all three joint components were found in 10 joints. The changes were predominantly local in nature as shown in Table III and loca-

Table III. Number of joint components with deviation in form or arthrosis only, divided according to extent of change.

grade 1 = local change

grade 2 = extensive change

Change	Deviation in form only		Arthrosis only	
	grade 1	grade 2	grade 1	grade 2
Joint component				
Temporal component	18	3	10	2
Condyle	27	9	0	
Disk	19	2	16	3

ted mainly in the lateral third of the joint.

In 21 joints both deviations in form and arthrotic lesions were noted. In 19 of these, morphologic changes in the condyle were combined with arthrosis in the disk, 18 of which revealed perforations. Of these 18 arthrotic disks, 13 were combined with arthrotic changes in the temporal component.

Of the total 24 arthrotic joints, 4 had extensive lesions. Fig. 3. In three the lesions were found in all three joint

components and in the fourth only in the temporal component and disk.

Of the 20 arthrotic joints with lesions of a local character (Fig. 4, 5) one showed changes in all three joint components. In 10 TMJs the arthrotic lesions were registe-

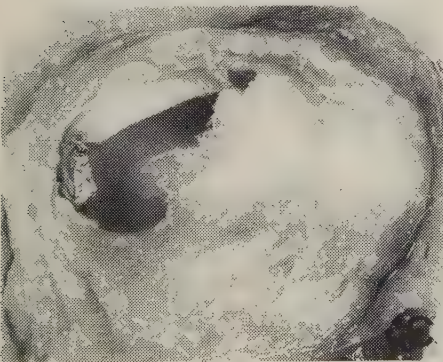
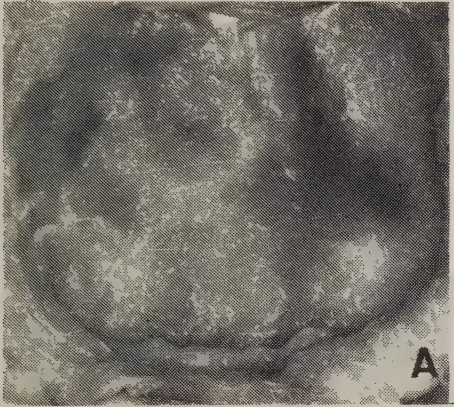


Fig. 3. Joint with extensive arthrosis.
 A: Temporal component (from below) is flattened with lesions in the lateral and central portions.
 B: Condyle (from above). The arthrotic lesion includes the entire superior portion with additional loss of substance laterally.
 C: Disk (from above). Extensive arthrotic lesion with large lateral perforation corresponding to the deep lesions in the other two joint components.

red in both the disk and temporal component. Six joints revealed arthrosis solely in the disk and three solely in the temporal component. The lesions were generally found in the lateral portions of the joints.

In the antero-posterior direction the lesions in the disk were most frequent in the middle dense portion and the corresponding articulatory surfaces on the posterior slope of the

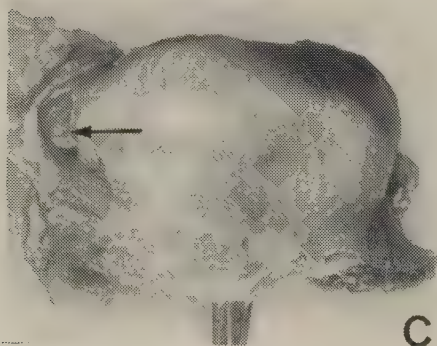
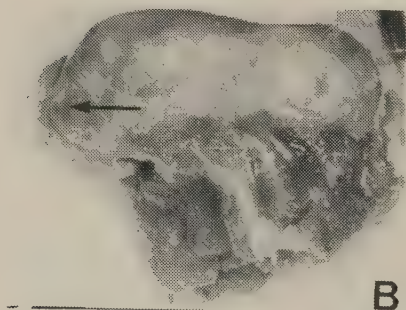
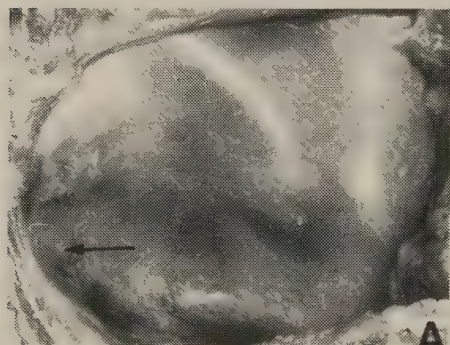


Fig. 4. Joint with local lateral arthrosis.

A: Temporal component (from below) with shallow arthrosis in the lateral wall of the fossa.

B: Condyle (from above) with lateral deviation in form, elevation and flattening of the condyle corresponding to the arthrotic lesion in the lateral wall of the fossa.

C: Disk (from above). Local perforation laterally corresponding to the changes in the temporal component and the condyle.

articular eminence and lateral wall of the fossa were also affected. From Table IV it is seen that the arthrotic lesions were mainly deep in nature. Dark-colored areas were detected in 12 TMJ disks indicating changes in the blood vessels in the posterior, lateral and central portions. These changes were divided evenly into disks with signs of arthrosis and disks with deviations in form.

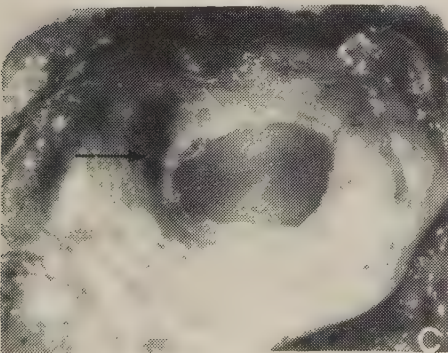
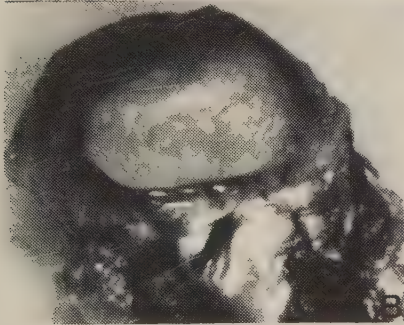
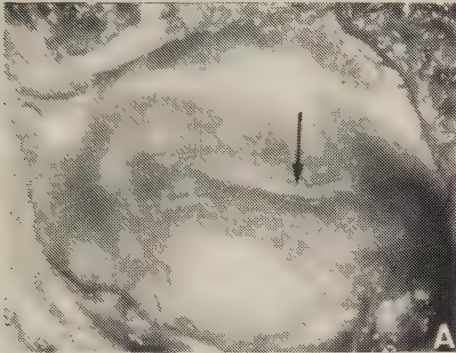


Fig. 5. Joint with local central arthrosis.

A: Temporal component (from below) with elevations and shallow arthrosis on the posterior slope of the articular tubercle.

B: Condyle (from above - in front) with marked deviation in form but intact joint surface.

C: Disk (from above) with arthrosis in the center corresponding to the marked elevation of the condyle and the arthrotic lesion on the articular tubercle during anterior gliding of the condyle-disk. Note dark-colored blood vessel invasion laterally in the normally vessel-free area of the disk.

Table IV. Depth of arthrotic lesions with respect to joint component.

Depth of lesion \ Joint component	Shallow	Deep
Temporal component	3	15
Condyle	0	4
Disk	1	20

DISCUSSION

During this study of the autopsy material we found two local shallow arthrotic lesions which were not noted by Öberg et al. (1971). These findings have later been verified by microscopic investigation. In individuals under 20 years of age all articulatory components of the TMJ revealed smooth joint surfaces, a condition necessary for disturbance-free movements in a functioning joint. A similar condition concerning form prevailed in approximately half of the adult material and was noted up to the oldest decade represented, even though remodelling in various tissue layers occurs throughout life. Hence, during favourable conditions these remodellings apparently do not result in deviations in form of such a character that they are accompanied by disturbances in joint function and TMJ clicking.

That deviations in form due to local thickenings of the articulating tissue layers can be one cause of "locking"/clicking in the TMJ is supported by a roentgenological examination of a clinical material (Nanthaviroj et al., 1976). In this study, deviations in form, with or without accompanying arthrosis, were seen in 45% of the adult joints. This also lends support to the idea that deviations in form seem to be a significant factor in the etiology of TMJ clicking, since clicking was also noted in a similar frequency during recent epidemiological studies (Helkimo, 1974; Hansson & Nilner, 1975). Similar agreement prevails between the results from the above-mentioned epidemiological studies concerning the occurrence of crepitation in the TMJ and the frequency of macroscopically detectable arthrosis.

Since biomechanical loading is an important etiologic factor for the occurrence of deviations in form as well as arthrosis (Öberg et al., 1971; Telhag, 1973) localization and extent of the changes reveal in both the medio-lateral as well as the antero-posterior direction the inter-componential relations during this functional loading.

Arthrotic lesions in the temporal component were most often localized laterally where they occurred predominantly in the wall of the fossa. Arthrotic lesions could not be shown in the most medial portion of the joint, either in this material or in a material from an investigation performed by Bean, Omnell & Öberg (1977). This finding probably

results from the fact that the condyle in a medio-lateral direction has a lesser extension than the temporal component (Öberg et al., 1971), that the condyle is localized laterally in the temporal component and that the lateral pole of the condyle appeared to lie higher than the medial pole in these joints. The localization of the arthrotic lesions to the lateral wall of the fossa in combination with lesions in the juxtaposed areas of the disk would seem to result from the condyle being pressed upwards or forced laterally during function. Superior movement of the condyle can be thought to occur after the loss of premolar and molar teeth. Öberg et al. (1971) confirmed the connection between arthrotic lesions and loss of such teeth.

Lateral movements of the condyle can be involved through occlusal interferences or appear in the condyle on the laterotrusion (working) side during bruxism or mastication. Arthrotic lesions on the posterior and inferior portions of the articular tubercle apparently depend on wear and pressure loading on the joint components during anterior gliding of the condyle-disk in connection with opening and lateral mandibular movements during, for example, chewing and especially bruxism.

An explanation for the differences present in the three different joint components concerning the frequency of deviations in form and arthrosis would seem to be related to differences in the reactive capacity against biomechanical pres-

tures between the three articulating joint components due to variations in histological construction. This appears to be particularly valid for the undifferentiated mesenchyme (proliferative layer) which during functional loading develops into fibrocartilage (Öberg, 1964; Carlsson & Öberg, 1974; Hansson et al., 1977). In the condyle there is found, even in older individuals, more remnants of such undifferentiated mesenchyme than in the temporal component (Hansson, 1977). This can explain why we found such a large number of deviations in form in the condyle while arthrotic lesions, on the other hand, were markedly fewer in the condyle than in the temporal component.

Deviations in form are accompanied by an increase in unfavourable biomechanical loading which leads to an arthrotic lesion in the joint component whose capacity to resist loading is exhausted. This is especially true concerning the disk which is lacking undifferentiated mesenchyme. Deviations in form in the disk, therefore, are dependent on form changes in the condyle and temporal component. These changes can then lead to a thinning and eventual perforation of the disk. The thin, vessel-free portion of the disk is often the first portion to be affected by arthrotic lesions and explains the high frequency of lesions seen in this component.

Another reason for the differences in the frequency of arthrotic lesions between the joint components can be that there exists a higher frictional loading between the disk

and temporal component than between the disk and condyle. This is possible because the disk, as a rule, follows the translatory movements of the condyle (Ramfjord & Blankenship, 1971; Öberg et al., 1971).

The dark-colored portions found in the posterior loose part of the disk suggest a traumatizing of these nerve- and vessel-containing areas that are not subjected to pressure loading under normal circumstances. Such a traumatizing must have great importance in the occurrence of pain symptoms from the TMJ as well as a traumatization of the attachment of the capsule laterally on the articular tubercle. Localization of deviations in form and arthrotic lesions in the above-mentioned region suggests that such a traumatization is by no means uncommon.

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SHRINKAGE OF TMJ TISSUES DUE TO HISTOTECHNICAL TREATMENT

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Right temporomandibular disks obtained at five autopsies of adults were immediately placed in physiological saline, after which they were cut into 4 equally thick sagittal slices. The width of the thinnest as well of the thickest portion of the dense middle part was measured with a special instrument graduated in 1/10 mm.

The slices were afterwards passed through 10% neutral formalin solution and 70%, 96% and 99.5% alcohol to xylene and measured again.

The preparations were then placed in paraplast with a melting point of 56-57°C. Three sagittal sections (5-6 μ) were taken from each slice and stained with eosin-haematoxylin, van Gieson's connective tissue staining and toluidine

blue, and the thinnest and the thickest parts were again measured in a Leitz light microscope with a measuring ocular.

Shrinkage during passage from physiological saline to xylene was significant ($p < 0.05$), but was less than 10% with 95% certainty. No difference in thickness was found between the slices treated up to xylene and the stained sections.

Key word: Shrinkage of TMJ tissues

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Submitted for publication, February, 1977

Conventional preparation of histological sections is always accompanied by shrinkage and distortion of the tissue. The changes are due to a variety of factors, such as dehydration, clearing, embedding, the angle of the knife of the microtome, the direction of the sectioning and thickness of the sections (Brain^{1 2} 1949). Investigations comprising measurement of the soft tissues of the temporomandibular joint condyle, temporal component and disk (Hansson et al. 1977, Hansson 1977) raised the question of shrinkage.

The present study was therefore undertaken to estimate the shrinkage of tissue due to treatment of specimens of the TMJ with conventional histological techniques.

MATERIAL AND METHOD

The material consisted of 5 adult human right temporo-mandibular disks obtained at autopsies. None of the specimens exhibited evidence of deviation in form or of arthrosis. Each disk was dissected free and immediately placed in physiological saline. The disk was divided into four equally thick sagittal slices after which the thinnest as well as the thickest part of each slice was measured with an instrument constructed by Ivansson. Fig. 1. The thick-

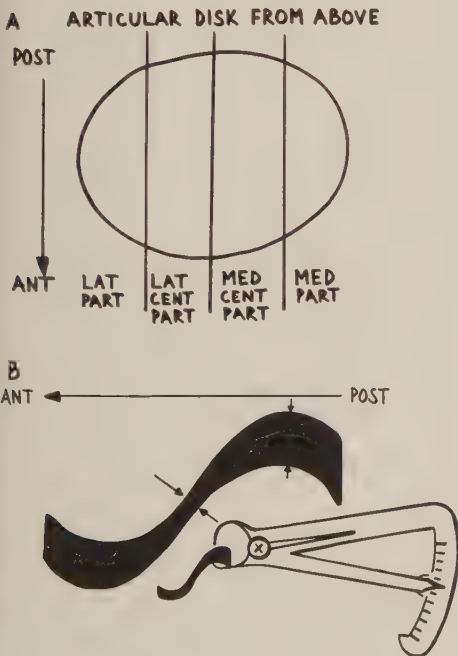


Fig. 1. A. Quartering of the articular disk. B. Ocular measurement with a gauge instrument according to Ivansson in the thickest respective thinnest measuring area of the dense part of each fourth of the articular disk. Medial aspect.

ness in each area was measured twice at an interval of half an hour and the mean (I) was calculated. The above procedures took all together less than 1 hour.

The slices were then placed in 10% neutral formalin solution for 5 days and afterwards dehydrated in 70% and 96% alcohol for each 24 hours, then in 99.5% alcohol for 8 hours. The specimens were finally deposited in xylene for a quarter of an hour, after which their thicknesses were determined with the gauge. After half an hour the measurements were repeated and the mean (II) was calculated for the thinnest and thickest parts of each slice.

The preparations were then placed in paraplast, which has a melting temperature of $56-57^{\circ}\text{C}$ and placed in the heating cabinet (60°C) for forty-eight hours.

With a Leitz sledge microtome 1400 three sagittal sections $5-6\mu$, were cut parallel to the surface of division. The direction of the sections was antero-posterior. The sections were stained with eosin-haematoxylin, van Gieson's connective tissue staining and toluidine blue. In each of these 3 differently stained sections the thinnest and the thickest areas were measured in a Leitz light microscope with a measuring ocular and the mean (III) of the 3 determinations was calculated.

Three quotients were calculated for each measuring area of the specimen.

- 1) II/I xylene/NaCl
- 2) $\text{II/III xylene/stained section}$
- 3) $\text{III/I stained section/NaCl}$

Since variance analysis of these quotients did not show any significant difference in shrinkage between the various regions of the disk or between measuring areas on one and the same disk (thickest and thinnest parts) the 40 quotients for each comparison were regarded as a single random sample.

The 95% confidence interval for shrinkage was calculated from the following formula,

$$\bar{z} \pm t_{0.025(39)} \times \frac{s_z}{\sqrt{40}}$$

where $\bar{z}$ and s_z denote the mean and standard deviation of the 40 quotients and where $t_{0.025(39)} = 2.02$ is a quantile in Student's t-distribution.

RESULTS

The 95% confidence intervals were

Shrinkage NaCl - xylene 0%-10%

" NaCl - stained section 0%-10%

" xylene - stained section -1.5%+2.5%

In other words, no difference in thickness was found between the slices treated up to xylene and the stained sections.

Shrinkage during passage from physiological saline to xylene, on the other hand, was significant ($p < 0.05$) but with 95% certainty it was less than 10%.

DISCUSSION

The material was small, but probably sufficient to give a

rough impression of the shrinkage of the dense collagenous fibrous and often cartilagenous connective tissue in the adult temporomandibular disk during routine histological preparation. The shrinkage (0-10%) observed in our material was only about half of that which can be calculated from the tables given by Brain^{1 2} (1949).

The difference can be largely explained by the fact that Brain studied embryonal tissue. In addition, embryonal tissue is most probably more readily distorted in association with sectioning than is dense collagenous cartilagenous tissue.

Evidently the shrinkage took place in the preparation to clearing, an observation in good agreement with what has been found in investigations of embryonal tissue.

In view of the similarity between the tissue in the deep part of the adult disk and the soft tissue of the condyle and of the temporal component (Öberg 1973, Carlsson & Öberg 1974) the findings are probably valid also for these tissues.

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THICKNESS OF THE SOFT TISSUE LAYERS AND THE ARTICULAR DISK
IN THE TEMPOROMANDIBULAR JOINT

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Hansson, T., Öberg, T., Carlsson, G.E. & Kopp, S. Thick-
ness of the soft tissue layers and the articular disk in
the temporomandibular joint. Acta Odont. Scand. 35, 1977

Out of 115 right temporomandibular joints from Swedish
subjects aged 1 day to 93 years, 48 joints without any gross
sign of arthrosis or deviation in form were examined histo-
logically.

The joint components were cut sagittaly, each into four
parts. Histological sections were made of the condyle, the
temporal component and of the articular disk. The total

thickness of the soft tissue layers was measured in decalcified sections, cut from the medio-central and lateral parts of the condyle and the temporal component and from the medial, medio-central, latero-central and lateral regions of the disk. In the medio-central sections from the condyle and temporal component the thickness of the fibrous connective tissue layer i.e. the surface layer was also registered. The soft tissue layers were thickest in the condyle superiorly, about 0.4-0.5 mm, in the temporal component on the postero-inferior slope of the articular tubercle, about 0.5 mm, and in the disk posteriorly about 2.9 mm. In the roof of the fossa it was only 0.1 mm. The soft tissue layers on the condyle as well as the disk were thinner laterally while the corresponding tissue in the temporal component was thicker laterally. The thickness of the soft tissue layers seem to reflect the growth and functional load to which the joint is exposed.

Key words: Anatomy; histology; human TMJ

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Received for publication, April 15, 1976

Judging from the description of the normal histology of the human temporomandibular joint (TMJ) and its structural changes with age (Öberg, 1973, Carlsson & Öberg, 1974), the arrangement and thickness of the tissue layers probably reflect the rate of growth and loading of the condyle and temporal component of the joint. The variation in thickness of the articular disk also indicates the topographic relation between the temporal component and the condyle.

Thus, it would be of interest to measure the thickness of the tissue layers in the different parts of the joint. Such measurements are also of importance for the radiological and the pathological diagnosis of diseases of the temporomandibular joint. The aim of this study therefore was to determine the normal range of variation of the thickness of the soft tissues and disk of healthy TMJ components.

MATERIAL AND METHOD

The original material consisted of 115 right temporomandibular joints obtained at autopsy from 1 day to 93 years old persons of both sexes (Öberg, Carlsson & Fajers, 1971). Forty-eight of these joints, which on macroscopic examination were classified as normal, i.e. without any sign of arthrosis or deviation in form, were used for the present investigation. The term arthrosis is used as a synonym for osteoarthritis, and degenerative joint disease.

The sex and age distribution of the 48 joints is given

in table I. After the right temporomandibular joint had been

Table I. Age and sex distribution of the material (n = 48)

Age (years)	0 - 19	20 - 39	40 - 59	60 - 93
Men	5	6	9	12
Women	6	1	5	4
Total	11	7	14	16

removed in block it was fixed in 5 per cent formaldehyde buffered to pH 7.4 with sodium barbiturate. The condyle, temporal component and disk were dissected free and examined. The findings were described not only verbally but also diagrammatically and photographically. The joint components were divided medio-laterally into four equal parts. Fig. 1. The late-

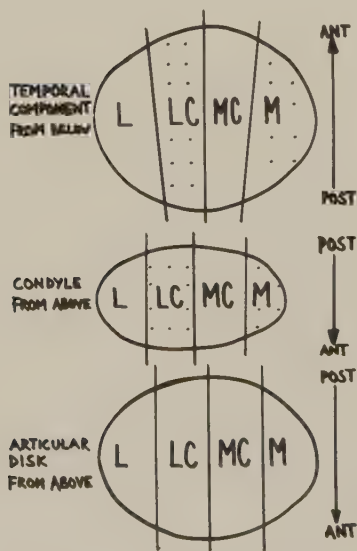


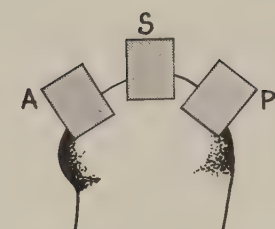
Fig. 1. Quartering of the joint components. The non-dotted parts were taken for decalcification and ordinary light-microscopic examination.

ral (L) and medio-central (MC) parts of the temporal component and of the condyle were decalcified in 0.5 M ethylene diaminetetracetate ($\text{Na}_2\text{H}_2\text{-EDTA}$) at pH 8.0 and embedded in paraffin. From these and from all four parts of the disk sagittal sections ($5\mu\text{m}$) were cut in the same direction and stained with haematoxylin-eosin, van Gieson and toluidine blue. (The latero-central (LC) and medial (M) parts of the condyle and temporal component were reserved for microradiography. The results will be reported separately.) The sections were examined separately by two examiners in a Leitz Wetzlar light microscope and furnished with a measuring ocular (10 mm = 100 scale lines).

The soft tissue consists of the 1) connective tissue lining (articular layer) and the subarticular layers which are 2) undifferentiated mesenchyme (proliferating layer) 3) transitional layer and 4) non-mineralized zone of cartilage in growing individuals; zone of hypertrophying cartilage (Überg, 1973; Fig. 2).

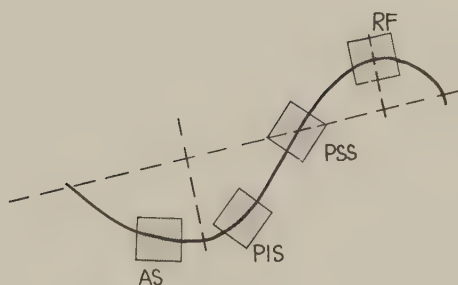


Fig. 2. The tissue layers in the superior part of the condyle from a 14 years old person. Htx-eosin. 1 = Connective tissue lining; 2 = Undifferentiated mesenchyme; 3 = Transitional layer; 4 = Cartilage; (5) = Area, where a compact bone layer develops when growth is finishing; 6 = Spongy bone.



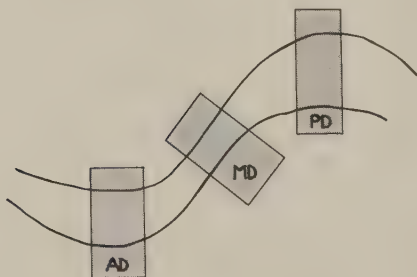
A ANTERIOR PART
S SUPERIOR PART
P POSTERIOR PART

Fig. 3. Sagittal section of condyle with measuring ranges. Medial aspect



AS ANTERIOR SLOPE
PIS POSTERO INFERIOR SLOPE
PSS POSTERO SUPERIOR SLOPE
RF ROOF OF FOSSA

Fig. 4. Sagittal section of temporal component with measuring ranges. Medial aspect



AD ANTERIOR DENSE PART
MD MIDDLE DENSE PART
PD POSTERIOR DENSE PART

Fig. 5. Sagittal section of the dense part of the articular disk with measuring ranges. Medial aspect

The total thickness of these tissue layers including the thin deepest zone of calcifying cartilage was measured in the following areas:

- 1) Condyle: anteriorly, superiorly and posteriorly. Fig. 3.
- 2) Temporal component: anterior slope, postero-inferior and postero-superior slopes of the articular tubercle and roof of the fossa. Fig. 4.
- 3) Articular disk: anterior, middle and posterior dense part. Fig. 5.

In the medio-central part of the temporal component and condyle the thickness of the articular layer (the connective tissue lining) also was measured separately.

The occurrence of the undifferentiated mesenchyme layer was registered for the different measuring areas in the medio-central parts of the temporal component and condyle.

The average values found by each examiner in the various areas measured in the three sections with different stainings were calculated. Since in a pilot study on 20 sections a t-test showed a close agreement between the examiners, the values noted by both examiners were pooled and the means were used for the statistical analysis. (Student's t-test) Significance levels considered were (x) $p < 0.05$; (xx) $p < 0.01$; (xxx) $p < 0.001$.

RESULTS

The total thickness of the soft tissue layers varied greatly

in different areas. Fig. 6, 7, 8 and 9. The mean values in

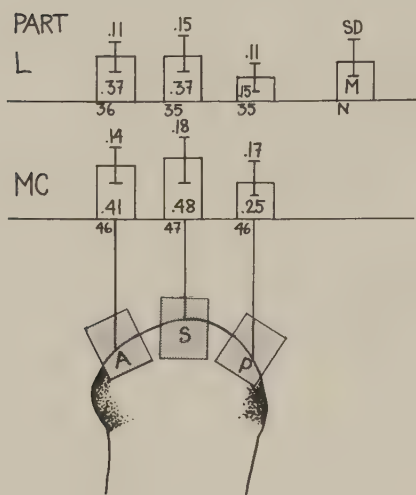


Fig. 6. Total thickness in mm of the soft tissue layers of the condyle. M = mean in mm. N = number of joints examined. The end points of vertical bar correspond to $M \pm SD$ (SD = standard deviation)

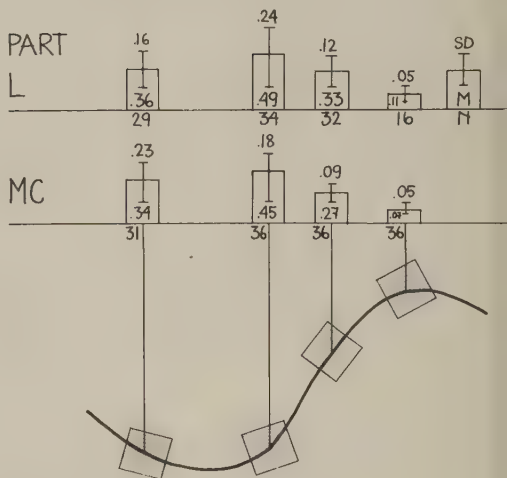


Fig. 7. Total thickness in mm of the soft tissue layers of the temporal component. M = mean in mm. N = number of joints examined. The end points of vertical bar correspond to $M \pm SD$ (SD = standard deviation)

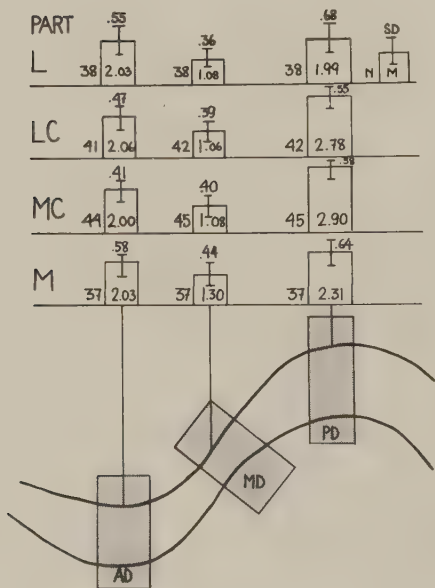


Fig. 8. Total thickness in mm of the dense portion of the disk. M = mean in mm. N = number of joints examined. The end points of vertical bar correspond to $M \pm SD$ (SD = standard deviation)



Fig. 9. Total thickness of the soft tissue layers in the TMJ components. Sagittal section.

the medio-central parts in the antero-posterior direction of the material as a whole were:

For the condyle the highest mean value was 0.48 mm superiorly, and the lowest mean value 0.25 mm posteriorly. In the temporal component the soft tissue was thickest on the postero-inferior slope of the articular tubercle, 0.45 mm, and thinnest in the roof of fossa, 0.07 mm. The articular disk was thickest posteriorly, 2.90 mm and thinnest in the middle part, 1.08 mm.

The total thickness in different parts medio-laterally varied somewhat, in as much as the soft tissues of the condyle was significantly (xxx) thicker centrally than laterally in the superior and posterior parts both of children and adults. In the temporal component the soft tissue layers tended to increase in thickness laterally, but significant differences were found only among the adult portion of the material on the postero-superior slope (x) of the articular tubercle and in the roof of the fossa (xxx). The middle (x)

and posterior (xxx) parts of the articular disk were significantly thicker medio-centrally than laterally in the adults. The anterior, middle and posterior dense parts of the disk in the children and the anterior part of the disk in the adults showed no such a difference in medio-lateral direction.

The connective tissue lining was thin. The thickest part of the condyle was superiorly 0.18 ± 0.06 mm and the thinnest part posteriorly 0.13 ± 0.04 mm. In the temporal component the maximum value was 0.20 ± 0.08 mm and found on the postero-inferior slope of the articular tubercle and the thinnest, 0.04 ± 0.02 mm, in the roof of fossa.

The subarticular soft tissue layers in the children were significantly (xx) thicker in all parts of the condyle with the highest values being found superiorly. No difference was found between the children and the adults in the temporal component. The postero-inferior slope of the articular tubercle in adults and the anterior slope in the children showed the highest values.

Undifferentiated mesenchyme was found in all children as a continuous or almost continuous layer in all parts of the condyle, while in the two oldest in this agegroup it had been reduced on the postero-inferior slope of the articular tubercle to solitary islands of cells.

In the adults there was in the areas with the thickest tissue layers significantly (x) less undifferentiated mesenchyme than in the thinner parts. Undifferentiated mesenchyme was missing in the anterior and superior parts of the condy-

le in respectively 25% and 40% of the examined joints and in the postero-inferior slope of the temporal component in 25%. The posterior part of the condyle and the roof of fossa contained undifferentiated mesenchyme in all but two cases.

DISCUSSION

The material of the present study was relatively small and most of the joints were obtained from men. Since, however, the primary selection of the original material was rigorous and since none of the joints had gross signs of arthrosis or deviation in form, the results can probably be regarded as representative of the thickness of the soft tissue layers in the healthy temporomandibular joint. Due to the fact that the joint components had been dissected free and thereafter sectioned perpendicularly to the respective joint surface, the values measured corresponded to the real thickness of the fixed soft tissue layers, disregarding the possible shrinkage, that resulted from the histotechnical treatment. The shrinkage of these actual tissues seems to be less than 10% (Hansson & Nordström, 1977).

Of the measured tissue layers in the temporal component and the condyle, the connective tissue lining has, as judged from experimental studies on animals, a slow turnover of matrix components (Öberg, 1964; Öberg et al., 1969). The layer is, like the disk, condried in pressureloaded areas.

The same studies show that in young individuals, the undifferentiated mesenchyme, the transitional layer and the

cartilage are sites of growth and of considerably quick new formation of tissues. The cell proliferation of the growth layers occurs almost exclusively in the undifferentiated mesenchyme (Folke & Stallard, 1966; Öberg et al., 1967). Via the transitional layer the undifferentiated cells develop into chondrocytes and a cartilaginous layer is formed in areas of rapid growth, while the cells in the transitional layer develop into osteoblasts which form bone in areas of slower growth (Öberg, 1964; Öberg et al., 1969). The last-mentioned studies also show that variations in the thickness of the growth layers indicate differences in the rate of growth.

In adults the cartilage persists or a cartilaginous layer is developed in areas exposed to heavy functional load. This layer, however, differs from that occurring during the growth period, by being, among other things, poorer in cells and richer in collagenous components. The occurrence of cartilage and variation in thickness of the entire soft tissue layer can therefore also reflect the loads to which different parts of the joint are exposed.

Except for the cartilage, the measured tissue layers contain only soft tissue. In the cartilage only the deepest 2-4 cells layers are mineralized, except in newborns where the major part of the cartilage is mineralized (Öberg, 1964). With the exception of areas where there is cartilage, the distance from the joint surface to the bony layer is thus a measure of the thickness of the soft tissue. The significantly thicker subarticular soft tissue layers in the condyle in

children indicate a rapid growth. The teenagers showed the highest values which corresponds to the results of studies of growth by Björk (1966). The thinness of subarticular tissues in the temporal component indicates a slower growth, while the relatively greater thickness in the articular tubercle indicates the site of growth in length of the temporal component and the growth in height of the articular tubercle, observed macroscopically by Öberg et al. (1971).

In the adults, the anterior and superior parts of the condyle and the postero-inferior slope of the tubercle had the thickest subarticular tissue layer. These parts of the joint are heavily loaded during function. The thickness of these tissue layers is dependent on an increase in the amount of cartilage tissue at the same time as the undifferentiated mesenchyme disappears in these parts. The growth capacity of the undifferentiated mesenchyme has probably been exhausted. In these areas, the articulating tissue layer also reaches its highest degree of chondrification. The thinner layers posteriorly on the condyle and in the roof of the fossa in the temporal component with an intact undifferentiated mesenchyme at a greater age shows that the functional load in these areas is rather small.

The lateral thinning out of the adult disk in the middle and posterior dense parts appear to be a result of the functional load, as the disk in children does not show this lateral decrease.

Acknowledgements. Thanks are due to laboratory assistant Birgitta Nordström for valuable work with the histological preparations and measurements and to civil engineer Tore Persson for his statistical help.

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THICKNESS OF THE SOFT TISSUE LAYERS AND ARTICULAR DISK IN
THE TEMPOROMANDIBULAR JOINTS WITH DEVIATIONS IN FORM

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Of 115 right temporomandibular joints from Swedish subjects, aged 1 day to 93 years, 24 of the 102 adult joints exhibited deviations in form. Twenty-two of these affected joints were examined histologically regarding the thickness of the soft tissue in the lateral and medio-central parts of the condyle and temporal component as well as in the lateral, latero-central, medio-central and medial parts of the disk.

The thickness of the soft tissue was measured microscopically on sagittal sections in the anterior middle and posterior parts of the joint components. The soft tissue layers were thickest in the lateral parts of the condyle superiorly, 0.6 mm: laterally on the anterior and postero-inferior slo-

pes of the articular tubercle of the temporal component, 0.6 and 0.5 mm, and posteriorly in the medio-central portion of the disk, 3.2 mm.

A highly significant negative correlation was found between the amount of undifferentiated mesenchyme and the thickness of the soft tissue layer, a finding clearly suggesting that the undifferentiated mesenchyme is utilized for remodelling of the tissue layers with deviations in form as a result.

The occurrence of undifferentiated mesenchyme and the total thickness of the soft tissue layers reflect the functional loading of the joint components.

Key words: Deviation in form of TMJ; Morphology: human remodelling

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Submitted for publication, February, 1977

Judging from previous postmortem investigations of the right temporomandibular joint from Swedes, aged 1 day to 93

years, deviations in form and/or primary arthrosis of the articulating components of the temporomandibular joint appear to exist in about half of the adult population (Öberg, Carlsson & Fajers, 1971; Hansson & Öberg, 1977).

The morphology and aging changes of apparently healthy temporomandibular joints have been elucidated by Öberg (1973) and Carlsson & Öberg (1974), and the thickness of the soft tissue layers and the disk have been measured by Hansson et al. (1977). In the last-mentioned investigation it was found that the mean value of the soft tissue thickness in the central part of the adult joint was highest (0.5 mm) superiorly in the condyle. In the temporal component the postero-inferior slope of the articular tubercle was thickest (0.5 mm), and lowest in the roof of the articular fossa (0.1 mm). The dense part of the articular disk was thickest (2.9 mm) posteriorly. The soft tissue layers of the condyle and of the disk were thinner laterally, while the corresponding tissue in the temporal component tended to increase in thickness laterally.

This paper concerns the thickness of soft tissue layers and the occurrence of undifferentiated mesenchyme in TMJs with deviations in form in an endeavour to elucidate the micromorphologic changes responsible for the development of gross deviations in form and surface lesions.

MATERIAL AND METHOD

From the original material, consisting of 115 right tempo-

romandibular joints obtained at autopsy from persons of both sexes, aged 1 day to 93 years old (Öberg et al., 1971), 24 joints were classified, after macroscopic reexamination, as joint with deviations in form without any signs of arthrotic lesions (Hansson & Öberg, 1977). These 24 joints were selected for the present investigation. On two occasions the histologic sections obtained were not acceptable. This left 22 joints for the investigation. The sex and age distribution of the 22 donors are given in Table I.

Table I. Age and sex distribution of the material

n = 22

Age (years)	20-39	40-59	60-93
Men	3	5	5
Women	3	4	2
Total	6	9	7

The total thickness of the soft tissue layers, including the thin deepest zone of calcifying cartilage, was measured in the lateral and medio-central parts of the condyle and the temporal component as well as the soft tissue layer of the articular disk. Fig. 1. All measurements were made from sagittal sections, according to a method described in detail by Hansson et al. (1977).

The articular layer (the connective tissue lining) was, as in the earlier investigation, measured separately in the

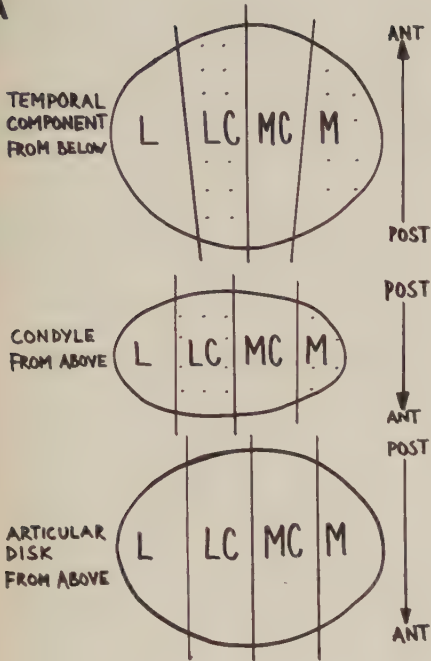
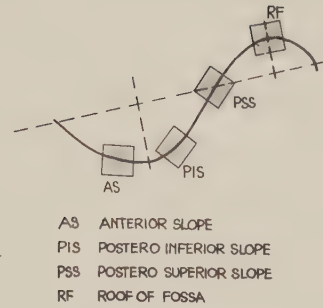
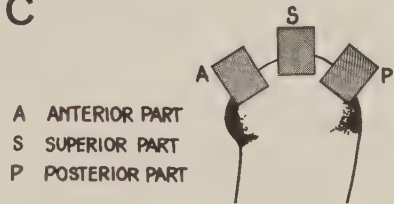
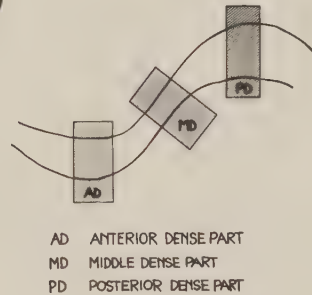
A**B****C****D**

Fig. 1. A. After the joint component had been dissected free, they were divided medio-laterally into four equal parts. From the lateral (L) and medio-central (MC) parts of the temporal component and of the condyle and from all four parts of the disk, sagittal sections were cut and stained with haematoxylin-eosin, van Gieson and toluidine blue. The total thickness of the soft tissue layers was measured in a light microscope with a measuring ocular. B. The four measuring areas of the temporal component. Medial aspect. C. The three measuring areas of the condyle. Medial aspect. D. The three measuring areas of the articular disk. Medial aspect.

medio-central part of the condyle and of the temporal component. In these parts of the joint components the amount of undifferentiated mesenchyme was also registered as a) no demonstrable undifferentiated mesenchyme, b) solitary islands of undifferentiated mesenchyme, c) almost continuous layer of cells or d) a continuous layer of cells.

For comparison between groups the Student's t-test for unpaired samples was used and for the test within groups the Student's t-test for ratios in paired samples.

Within each joint Spearman's rank correlation coefficient was calculated as a measure of the covariation between the amount of mesenchyme and the thickness of the soft tissue layers.

RESULTS

It was often difficult to obtain acceptable histologic sections for measurements in all parts of the joint. The greatest soft tissue thickness was measured for the condyle superiorly, in the lateral part, 0.58 ± 0.22 mm (Fig. 2.): for the temporal component laterally, on the anterior and postero-inferior slope of the articular tubercle, 0.55 ± 0.24 mm and 0.52 ± 0.27 mm respectively (Fig. 3.): and for the disk posteriorly, in the medio-central portion, 3.21 ± 0.77 mm (Fig. 4.).

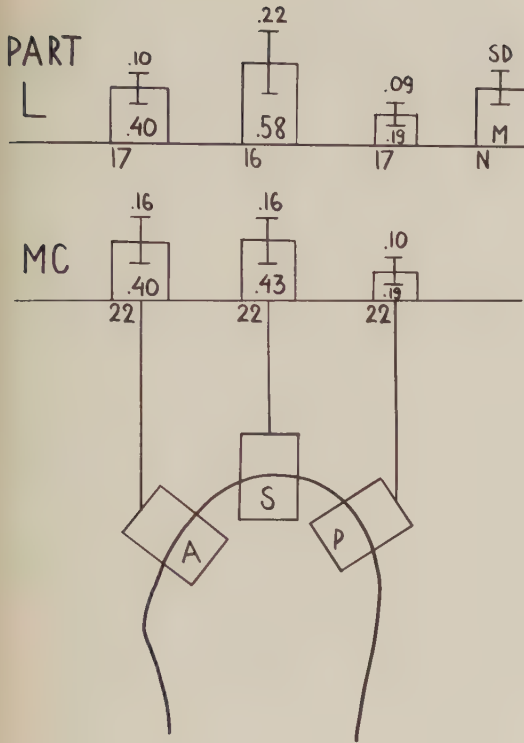


Fig. 2. Total thickness in mm of the soft tissue layers of the condyle. M = mean in mm. N = number of joints examined. The verticals denote $M \pm 1 SD$ (SD = standard deviation).

In the sagittal plane the disk was significantly thickest ($p < 0.001$) posteriorly except in the lateral fourth of the joint, where there was no difference ($p > 0.05$) between the anterior and the posterior dense parts of the disk.

No difference in thickness of the soft tissue layer was found in medio-lateral direction except in the anterior slope of the articular tubercle, where the lateral parts were somewhat thicker ($p < 0.05$) than the medio-central parts. In the middle dense part of the disk the medial parts were somewhat thicker ($p < 0.01$) than the adjacent lateral parts and in the posterior dense part the medio-central portion was some-

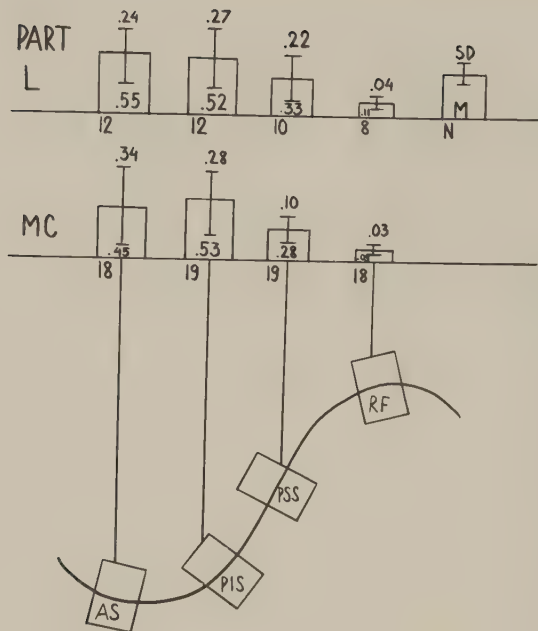


Fig. 3. Total thickness in mm of the soft tissue layers of the temporal component. M = mean in mm. N = number of joints examined. The verticals denote $M \pm 1$ SD (SD = standard deviation).

what thicker ($p < 0.01$) than the lateral one.

The connective tissue lining of the condyle was thickest (0.19 ± 0.06 mm) anteriorly and superiorly.

In the temporal component the connective tissue lining was thickest in the postero-inferior slope of the articular tubercle (0.22 ± 0.09 mm) and thinnest (0.05 ± 0.03 mm) in the roof of the fossa.

Undifferentiated mesenchyme was seen more often as a continuous layer of tissue in the condyle than in the temporal component. But in both components the amount of such mesen-

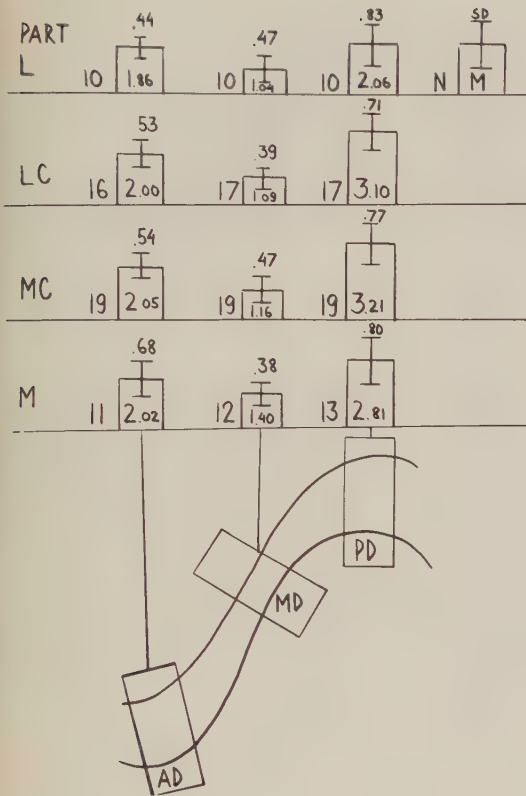


Fig. 4. Total thickness in mm of the dense portion of the disk. M = mean in mm. N = number of joints examined. The verticals denote $M \pm 1$ SD (SD = standard deviation).

chyme varied widely. Undifferentiated mesenchyme was completely missing in the anterior part of the condyle in 9 (41%) of 22 joints examined, in the superior part of the condyle in 13 (59%) of 22 joints examined and in the anterior, postero-inferior and postero-superior slopes of the articular tubercle in 27%, 78% and 32%. Fig. 5.

In all but one of the joints examined the roof of the fossa in the temporal component and the posterior part of the condyle contained undifferentiated mesenchyme that had, however, been reduced to solitary islands or an almost conti-

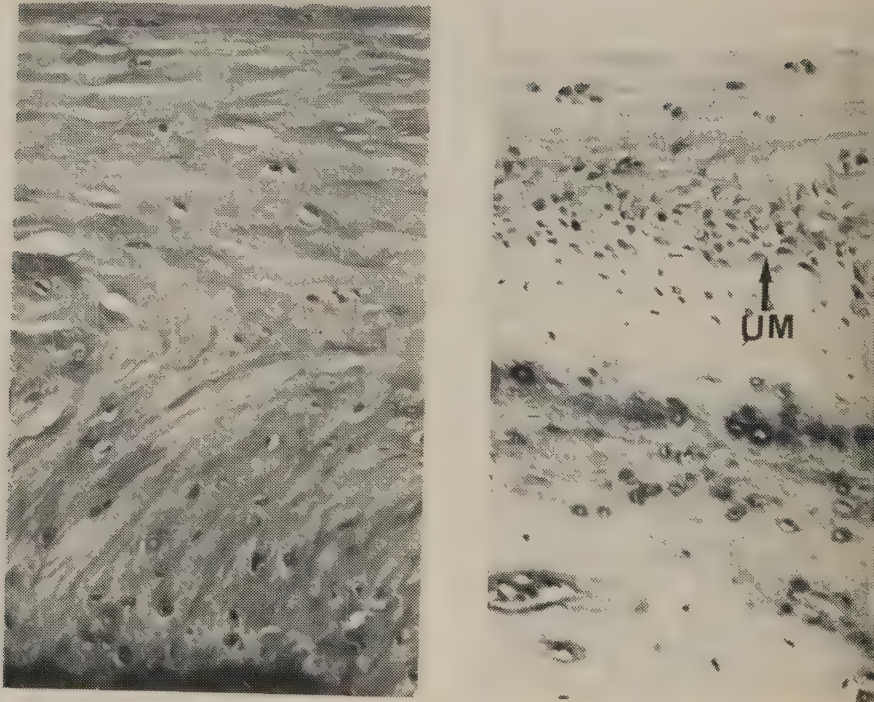


Fig. 5. Left. Undifferentiated mesenchyme completely missing in the superior part of a condyle from a 52 year old woman. Right. Same condyle but with an almost continuous layer of undifferentiated mesenchyme (UM) in the most anterior part

nuous layer of cells. A sign test of the rank correlation coefficients according to Spearman showed a highly significant number of minus signs. The amount of undifferentiated mesenchyme and the thickness of the soft tissue layer thus clearly varied inversely ($p < 0.001$).

A comparison between the previously studied 48 healthy TMJs i.e. temporomandibular joints without signs of arthrosis or deviation in form from the same original material (Hansson et al. 1977) showed that the soft tissue layers were thicker



Fig. 6. Difference in total thickness of the soft tissues between healthy TMJ (left) and TMJ with deviations in form (right). Sagittal section.

in these joints with deviations in form. Fig. 6.

Significant differences were, however, found only laterally on the anterior slope of the articular tubercle ($p < 0.05$) and medio-centrally in the roof of the fossa ($p < 0.01$) of the temporal component. On the condyle significant differences were found laterally on the superior ($p < 0.001$) and posterior ($p < 0.05$) parts.

DISCUSSION

Although the material was small, its age and sex distribution was fairly normal. The results should therefore leave a correct impression of the thickness of the soft tissue in TMJs with deviations in form.

In the lateral parts of the joints it was often difficult to obtain acceptable measurable histologic sections because it was sometimes not possible to place the plane of section

perpendicular to the surface of the joint, for example, in the lateral wall of the fossa of the temporal component. This is the reason why it was not always possible to obtain values in all of the measuring areas.

The thickness of the connective tissue lining did not differ from what has been found in healthy joints. This is in agreement with findings in studies of animal experiments that the surface layer has a slow turnover of matrix components and adapts itself more or less passively to remodelling processes in the underlying tissue (Öberg, 1964; Blackwood, 1966; Öberg et al., 1969).

In this material the amount of undifferentiated mesenchyme in the medio-central part of the joint was relatively little, especially in those areas subjected to the largest functional loads i.e. anteriorly and superiorly on the condyle as well as the anterior, postero-inferior and postero-superior slopes of the articular tubercle. In the lateral quarter of the joint components the soft tissue layer was still thicker, a finding suggesting a still larger reduction of the amount of undifferentiated mesenchyme laterally. This lends support to the opinion that increased biomechanical loading stimulates the growth of cartilage from the undifferentiated mesenchyme with simultaneous thickening of the soft tissue layer. It would seem that the undifferentiated mesenchyme offers protection against injury by unfavourable loading of the joint components (Hansson et al. 1977). Since the undifferentiated mesenchyme in children is primarily made up of more closely packed cells, and has a larger growth

capacity, and since coherent rests seen in the present material were larger in the condyle than in the temporal component, it might be possible to explain the higher frequency of deviations in form, and the fewness of the cases of pure arthrotic injuries in the condyle in arthrotic TMJs commonly showing perforation of the disk and surface injury to the temporal component (Hansson & Öberg, 1977).

The differences in thickness found between healthy TMJs and the joints from the present material were obviously due to new formation of cartilage from the undifferentiated mesenchyme.

In contrast with what was seen in healthy joints in which the soft tissue layer on the condyle was thinner laterally than medio-centrally it was the other way round in the joints with deviations in form. This was probably because of the lateral position of the condyle in the fossa and/or the increased functional loading of the lateral parts of the joint in association with lateral and protrusion movements, especially in bruxism or when the lateral pole of the condyle is situated higher than the medial pole (Hansson & Öberg, 1977).

In good agreement with the results of the macroscopic re-examination of the entire autopsy material (Hansson & Öberg, 1977) the disk was thinnest laterally also after sectioning and measurement in the microscope, where on account of the thickening of the other parts of the joint components it had been subjected to greater pressure during function without the ability to compensate the extra load due to its nature of collagenous fibrous connective tissue.

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